Restoration Management Plan For the Lower Darby Creek

with recommendations for the John Heinz National Wildlife Refuge at Tinicum

DELAWARE RIVERKEEPER® NETWORK

May 2006

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The Delaware Riverkeeper Network (DRN) is the only advocacy organization working throughout the entire Delaware River Watershed. The Delaware Riverkeeper is an individual who is the voice of the River, championing the rights of the River and its streams as members of our community. The Delaware Riverkeeper is assisted by seasoned professionals and a network of members, volunteers and supporters. Together they form DRN, and together they stand as vigilant protectors and defenders of the River, its tributaries and watershed. DRN is committed to restoring the watershed's natural balance where it has been lost and ensuring its preservation where it still exists.

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Prepared for:

Friends of the Heinz Refuge

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FOREWORD

The John Heinz National Wildlife Refuge at Tinicum is a unique resource for the Delaware River, its citizens, and natural inhabitants. The Refuge has undergone centuries of change through diking, ditching, filling, dredging, and agriculture. More recently pollution, urbanization, invasive species colonization, and other influences have made their own unique impact. Restoring full ecological health, as a result, will also take time.

In developing this restoration plan, the Delaware Riverkeeper Network undertook a series of investigations into the complex alterations of the Refuge. Through a combination of historical research and field data collection, Restoration Program staff identified the impacts directly affecting ecological health and developed recommendations on how and where to address these issues. This plan is the culmination of that process. It is the hope of the Delaware Riverkeeper Network that this work will provide valuable insight and direction as the Refuge develops its Comprehensive Conservation Plan.

Planning is merely the beginning of the restoration process. After problems have been identified and solutions proposed, implementation must follow in order to make plans worthwhile. The Delaware Riverkeeper Network has worked throughout this process to create a plan that will be facilitate its application through outlining a restoration management philosophy and identification of projects, techniques, problem locations, and prioritization.

While the Refuge and its surrounding influences are continually changing, this plan guides ecological restoration based on the culmination of effects on today's ecosystems. With this understanding, the highest priority is to prevent future impacts. Being located in one of the busiest estuaries in North America, there will be future impacts that will pose harm to the Refuge. Protecting it from these future threats is the most cost-effective measure a restoration program can implement.

Having been severely altered over the course of more than three hundred years, the Refuge is anything but pristine. However, despite this long history of alteration, it still contains intact freshwater tidal marsh and provides habitat for a number of rare, threatened, and endangered species. The ability of Refuge lands and its species to adapt to these changes characterizes the area's natural tendency to self-restore. The guidance provided by this plan will aid the U.S. Fish and Wildlife Service and its community of partners to assist this natural process where it is occurring, and direct it where it has been lost.

Maya K. van Rossum
The Delaware Riverkeeper

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EXECUTIVE SUMMARY

The John Heinz National Wildlife Refuge at Tinicum is a regional and national treasure. The Refuge contains a long and detailed history of interactions between humans and the land and waters of the area. This history has affected (and in many cases created) the ecosystems we see today. The ecological state of the Refuge in 2006 is the culmination of the positive and negative influences of past generations.

The Delaware Riverkeeper Network undertook historic research, field data collection, and analysis of existing plans and research in order to identify the underlying causes of degradation, characterize the current condition of the ecosystems, and identify solutions that would restore ecological structure (physical features), composition (species assemblages), and function (biological, hydrologic, chemical) where it has been degraded or lost.

While this report discusses a number of ecological issues affecting the Refuge today, three major issues pose significant impacts to its ecosystems:

1. Excessive Deer Browse: The Refuge is an island of biological diversity within a highly urbanized area. One of the human impacts of the region has been the loss of predator populations, which naturally maintain population levels of other species. Large deer population levels, combined with a lack of additional foraging area, has created intense herbivory pressure on vegetation. As a result, many plant communities have been altered in both structure (i.e., loss of shrubs, tree regeneration) and composition (ie. loss of plant diversity, promote spread of invasive species).
2. Invasive Species Colonization: The excessive herbivory and large-scale disturbances of the past century (marsh ditching/dredging/filling, adjacent construction activities) have created ideal habitats for many exotic, invasive species. Seventeen invasive species were identified as posing significant threats to biodiversity, plant community composition, and ecological functions (altering feeding relationships, soil biogeochemical processes, and habitat availability).
3. Loss and Alteration of Freshwater Tidal Marsh: Freshwater tidal marshes are some of the most productive ecosystems in the world, providing habitat for a variety of terrestrial and aquatic species. Nearly all of the land encompassed by (and surrounding) the Refuge today was, at some time, freshwater tidal marsh. Dredging, filling, or diking over the past 350 years has reduced thousands of acres into the mere 200 that remain. As such, a large portion of restoration at the Refuge is focused on restoring existing degraded areas into freshwater tidal marsh.
4. Pollution Impacts: Being surrounded by a highly urbanized watershed, the Refuge has been severely impacted by numerous pollution sources. Some major sources, such as Folcroft Landfill, will require years of intensive cleanup before pollutants are reduced. However, the majority of pollution sources are a result of the combined effect of numerous urban sources including impervious surfaces, stormwater runoff, and thermal pollution. These effects can only be reduced through addressing their sources throughout the Darby Creek watershed.

The Refuge has been continually altered for the past three centuries. While progress can be made quickly, restoring the ecological health of the Refuge will likely take decades, if not longer. With the investment of time and resources of federal and state governments, local municipalities, and concerned citizens, the goals and performance standards outlined within this plan will be achieved. This plan is the first step toward that success.

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1. INTRODUCTION

1.1. Restoration Management Plan Purpose

In summer of 2005, the Friends of the Heinz Refuge (FOHR) and the U.S. Fish and Wildlife Service (USFWS) requested the Delaware Riverkeeper Network's assistance to develop an ecological restoration plan to guide ecosystem management at the John Heinz National Wildlife Refuge at Tinicum (herein referred to as "Refuge").

The purpose of this plan is to initiate an ecological restoration approach to management at the Refuge. Previous plans and studies have made calls for preserving, maintaining, and restoring the habitats and ecosystems associated with the Refuge. This plan, and its recommended actions, is focused on the active pursuit of those goals.

The Society for Ecological Restoration International (SER) defines ecological restoration as *the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed* (SER 2004*)*. Due to factors such as public use, Refuge management goals, and historical and modern land use, true ecological restoration may not be suitable (or possible) for all portions of the Refuge. Therefore, this plan includes not only restoration recommendations, but habitat enhancement and ecological engineering recommendations as well. In development of this plan, Delaware Riverkeeper Network has attempted to distinguish the three types of management activities.

1.2. Site Location and Setting

The Refuge is located in Philadelphia and Delaware Counties, about one mile north of Philadelphia International Airport. The Refuge was established by an act of Congress in 1972 to protect the one of the last areas of freshwater tidal marsh in Pennsylvania (USFWS 2006). The tidal freshwater marsh at the Refuge now comprises approximately 80% of the state's coastal wetland. The Refuge represents an important migratory stopover along the Atlantic Flyway that provides a mix of freshwater habitats. It also provides protected breeding habitat for state listed threatened and endangered species, as well as many neotropical migrants (Cohen 2004).

The Refuge is located downstream of the Darby Creek watershed. Cobbs Creek joins with Darby Creek about one mile upstream from the Refuge. Collectively, the Darby and Cobbs watersheds drain a largely urbanized region containing numerous stormwater discharges, large areas of imperviousness, combined sewer overflows (Cobbs only), and 8 permitted industrial and municipal wastewater discharges (DCVA 2004).

A view of the Darby Creek upstream of the Refuge. Photo: D. Salas

Impervious area[1] ranges in the Darby Creek watershed from 28.8 to 51.4 percent with the higher percent imperviousness found in the lower reaches (DCVA 2004). Studies document that aquatic life impacts can be compromised in watersheds with impervious areas of 10% or even lower. Degradation of streams and wetlands is clearly evident when impervious surface reaches 10%. Some estimates are emerging that degradation occurs with as low as 8% impervious coverage (Arnold and Gibbons 1996).

[1] The amount of paved or hard surfaces.

Watershed imperviousness of 4% (the equivalent of one house per every 2 acres) can cause impairment for sensitive aquatic species. At 25% imperviousness, fish species begin to die. At 30% imperviousness, degradation is severe (Arnold and Gibbons 1996).

Consequently, the Darby-Cobbs watershed has experienced increased flooding of low lying urban areas, "flashy" stream flows, accelerated stream bank erosion, and degraded water quality over the past century. Watershed restoration efforts have begun along portions of the watershed. Darby Creek Valley Association and the Philadelphia Water Department are active in promoting watershed management and conservation. Although Darby Creek flows through the Refuge, it is also upstream from the tidal Delaware River. As a result estuarine waters flow into (upstream) Refuge lands at periods of high tide. Therefore, the ecological health of the Refuge, and in turn, the health of the Delaware Estuary is interrelated.

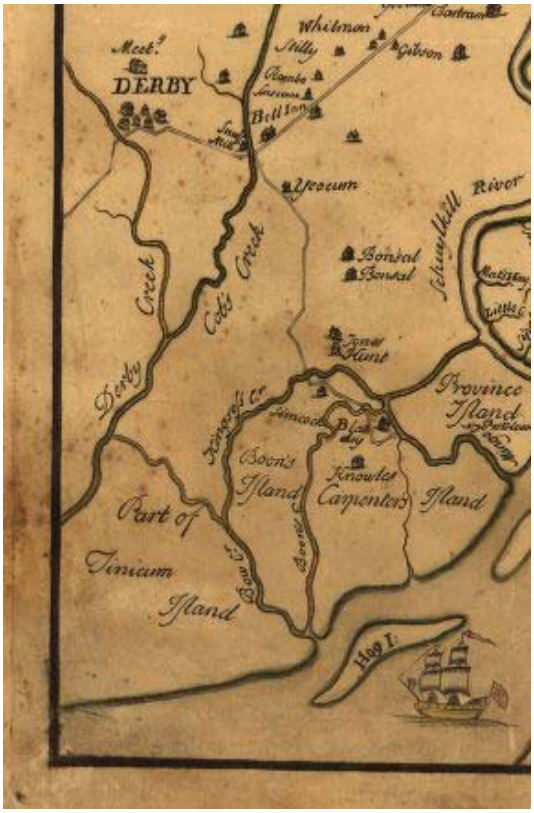
2. HISTORIC IMPACTS AND RELATION TO RESTORATION ECOLOGY

2.1. Historic Impacts to the Tinicum Region and Refuge Lands

The land encompassing the Refuge has been inhabited for hundreds, if not thousands of years. No doubt, this area's ongoing relationship with different cultures and land ethics throughout the centuries has had many impacts on the Refuge as it is known today.

Prior to European settlement, the Lenape and earlier inhabitants likely utilized (and consequently "managed") the marsh and upland habitats around Tinicum Island. Earliest European settlement of the Refuge area is dated as early as 1643, when Colonel John Printz established a settlement at Tinicum that served as the seat of the Swedish government in North America for 12 years until it was surrendered to the Dutch (Stevens 1964).

American settlements in the 1600's were attracted to the Tinicum region for its strategic and productive landscape. Its location along the Delaware River, with close proximity to Philadelphia and Wilmington, made it a desirable location for trade and transportation. European settlers also found the marshes to be familiar terrain and easier to convert to agriculture than the expansive forest in the adjacent uplands. The following describes the extent of forests experienced by early settlers in this region:



Map detail, A Map of Philadelphia and Parts Adjacent*, 1752. Scull and Heap*

> *...Towering tulip trees reared their smooth trunks to great heights. Huge beeches with silvered boles, rough barked chestnuts walnuts, hickories, maples, buttonwoods and ash trees strove with each other for space to spread their branches... Among the greater trees the lesser, sassafras, dogwood, hombeam, holly, alder, and a multitude of shrubs elbowed each other…Only by the few Indian trails was such a forest penetrable without vast difficulty and real danger* (Delaware Tercentenary Commission 1938).

Impoundments around Tinicum are believed to have been built as early as the 1640's by either the Swedes or the Dutch. Dikes were constructed around Tinicum in order to isolate marsh areas from the tidal flows of the Delaware River in order to utilize the rich silt soil for agriculture. The dike systems were expansive and significantly altered the hydrology of tidal marshes and adjacent ecosystems along the Delaware River, Darby Creek and their tributaries.

Later records show that British soldiers breached dikes and floodwalls near Essington in 1777. By 1788, the Pennsylvania legislature had passed four acts for the maintenance and expansion of dikes in and around Tinicum. Maintenance outlined in the acts include orders to "mow and keep them clean" and to " cut three times a year" species such as elderberries (*Sambucus canadensis*), pokeweed (*Phytolacca americana*), thistles (*Cirsium spp*.), burdock (*Arctium minus*), and other "weeds which may be injurious to the said meadows…" (McCormick 1970). Agricultural use (pasture and cropland) of the diked areas appears to have continued up until the early 20th century.

Events that destroyed or highly altered what is now Refuge lands over the 20th Century are well documented in *Two Studies of Tinicum Marsh* (McCormick 1970). One of the first impacts of the 20th century was the construction of the Philadelphia and Chester Railway Company, a trolley service that provided direct transit between Chester and Philadelphia from 1901 to November 1946 (Schieck and Cox 1970). Photos of the rail line (taken between 1917 and 1919) in the vicinity of the Refuge show adjacent areas with extensive marsh dominated by what appears to be tussock sedge (*Carex stricta*). This indicates that the areas surrounding the railway were still primarily wetland, but not tidal. It is unclear whether the lack of tidal influence in the photos is a result of some impact (i.e., the existing dike system) or the location's natural hydrology. Regardless, the construction of the railway impacted these areas with extensive cut and fill operations along its corridor. This rail ran along what today is the southern access road along the impoundment where some railroad ties are still visible in the roadbed.

Map detail, Map of Philadelphia, Wilmington, and Baltimore Railroad showing its connections*, 1838. Larkin.*

The 1930's saw numerous, and expensive, repairs and alterations by the U.S. Army Corps of Engineers ("the Corps"). The federal Works Program Administration, Pennsylvania legislature, and Delaware County all appointed funds to repair the dikes along the southern edge of Darby Creek. In 1935, a proposal for mosquito control led the Corps to construct a series of ditches throughout Tinicum marsh. Some of these man-made channels are still visible today in the northern half of the freshwater tidal marsh.

From the 1930's until the 1950's, several areas around Tinicum were utilized by the Corps for hydraulic landfills of dredged material. One area of the Heinz Refuge impacted by these activities includes the Henderson Dike area, which was filled during this period (McCormick 1970).

2.2. Preservation and Restoration of Tinicum Marsh

The 1950's also saw the first protection efforts in the Tinicum region. In 1955, the Gulf Oil Corporation donated a diked, non-tidal area of 145 acres, adjacent to the eastern end of Tinicum marsh to the City of Philadelphia "to be administered for the benefit of wildlife and people." This became known as the Tinicum Wildlife Preserve (UWFWS 2006). This preservation of this property along with growing concerns over the impact of industrial facilities along Darby Creek led to the creation of the Concerned Area Residents for the Preservation of Tinicum Marsh, or CARP (McKeown 2001).

The preservation of Tinicum marsh resulted directly from the efforts of a few individuals and constitutes a significant turning point in the area's history. In 1969, Jean Diehl, a local resident and president of CARP, started a grassroots effort to preserve the Refuge. In 1970, the *Two Studies of Tinicum Marsh* was published in part to document the high environmental value of the area. After testifying before Congress in 1972, CARP raised over $100,000, which resulted in the acquisition of 1,200 acres of the Refuge and establishment of the Tinicum National Environmental Center (McKeown 2001).

The early 1970's also saw the construction of Interstate 95 (I-95) and an interchange system with State Road 420. These major changes resulted in the dredging and filling of additional marsh areas. The impacts of this major alteration is discussed in more detail in Section 3.3.

The Folcroft Landfill operated from the 1950's through the 1970's accepting municipal, demolition, and hospital waste. The Landfill was closed in 1973 as a result of permit violations and improper management. Closing activities included regrading of the landfill, reducing steep slopes along with covering and seeding the site (USEPA 2006).

In 1980, Congress authorized the purchase of the Folcroft Landfill to increase the size of the Refuge. At this time, the U.S. Environmental Protection Agency (the EPA) remains in discussion with potentially responsible parties regarding investigation of the Landfill's contamination (USEPA 2006). The Refuge is to facilitate the Landfill clean up efforts.

In 1991, through a bill sponsored by Congressman Curt Weldon, the Tinicum Wildlife Preserve officially became the John Heinz National Wildlife Refuge at Tinicum in honor of the late Senator who was influential in the marsh's preservation..

In February 2000, a surface pipeline located on the Refuge ruptured, leaking over 19,000 gallons of crude oil into the 145-acre impoundment. This leak adversely impacted the open waters of the impoundment, and adjacent riparian forests, meadows, and non-tidal wetlands. The spill site was reviewed and subsequently restored during 2001 and 2002 under a Natural Resource Damage Assessment initiated through Pennsylvania Department of Environmental Protection, Pennsylvania Fish and Boat Commission, the USFWS, and the EPA.

The cultural history of the region reflects changing societal values in the United States. The Lenape and earlier indigenous people, along with European explorers and settlers valued the marshes and adjacent uplands for agriculture, fishing, and hunting along with its strategic location for trade and transportation. As the Tinicum region developed, the perceived value of marshes diminished and were subsequently filled or dredged. Over the past 50 years, the history of the Refuge reflects a renewed and refined sense of ecological value.

These changing values and land uses have been experienced in many coastal communities across the United States. As one of the earliest permanent European settlements on the Atlantic coast, the Tinicum region serves as a prime example (Casagrande 1997). This history provides insight into the challenges facing the Refuge today and encouragement for strides being made toward preservation and restoration of the Refuge. Key lessons for future management include:

1. The Refuge represents much more than Pennsylvania's largest tidal freshwater wetland, it also represents a remarkably successful history of over 50 years of community-based conservation.
2. Despite this long history of alteration, the Refuge's remaining tidal wetlands are host to a number of rare, threatened, and endangered species. The identification *and prevention* of future impacts is the most cost-effective measure that can be implemented to preserve these rare, threatened, and endangered species.

3. Early landowners cooperated in maintaining conditions for agriculture, including the drainage system of dikes and ditches and weed management. Today's regional issues, such as stormwater, water pollution, and invasive plant colonization, likewise cannot be addressed only within the Refuge. Successful management must involve surrounding communities and their residents who benefit from the
   Refuge's ecological services and its aesthetic, educational, recreational values.
4. The combined effort and commitment of concerned citizens along with local and federal government has protected over 1,000 acres of important habitat for many plants, fish, and other wildlife, including several threatened and endangered species.

3. MODERN IMPACTS AND RELATION TO RESTORATION ECOLOGY

3.1. Ecologically Unsustainable Deer Densities

The abundance of deer populations throughout the Delaware River watershed is well documented. As a result of numerous social, political, and ecological factors, deer populations in many areas have increased (or have been maintained) at levels that are unsustainable to the ecosystems they inhabit. Field surveys of the Refuge strongly indicate that the current deer population is at an unsustainable level. Deer impacts on ecosystems observed include:

1. All of the forested communities surveyed contained a low abundance of shrubs and tree regeneration.
2. Herbaceous species of the forested and meadow communities surveyed contained low native species diversity.
3. Species richness was dominated by native and/or invasive species considered to be of "low palatability" or "browse adapted" to deer.

The effects of high deer populations on ecosystems have been found to impact plants and wildlife in numerous ways. Most of the examples cited within this section are detailed in the report generated from the Pennsylvania Deer Management Forum Report titled *Managing White-tailed Deer in Forest Habitat From an Ecosystem Perspective: Pennsylvania Case Study (*Latham et al. 2005*)*. Some of these impacts are already visible at the Refuge, while others remain either undetermined or potential. Because so many portions of the Refuge exhibit deer-related impacts, the plan recommends as a primary effort addressing these effects. As discussed in this section, the size of the Refuge deer population directly affects ecosystem structure, composition, and function.

Reduction of flora species diversity and richness is a commonly noted effect of deer overpopulation. On long affected sites, the establishment and dominance of browse resilient species often is the result. Consequently, deer browse can have a measured effect on the balance between native and introduced species. Studies have repeatedly shown that deer avoid invasive species such as garlic mustard (*Allaria petiolata*), Eurasian honeysuckle (*Lonicera spp.*), Japanese barberry (*Berberis japonica*), and tree-of-heaven (*Ailanthus altissema*) if other sources of food are available (Latham et. al. 2005). Deer abundance also alters ecosystem structure by reducing densities of understory trees and eliminating shrubs. Research in central Pennsylvania indicated that the occurrence of canopy gaps increased by 41% on lands where deer control efforts were prohibited as compared to state lands where control efforts were undertaken. (Pederson and Wallis 2004).

The adverse effects of high levels of deer browse are not limited to plant species. Research shows that deer browse alters ecosystems to the extent that they become unfavorable habitats for other wildlife. Gray squirrel, white-footed mouse, and some amphibians species have been shown to decline in areas highly browsed by deer (Elliot 1978; Nixon and Hanson 1987). Subsequently, predators of these species, owls, hawks and other carnivores, decline (Flowerdew and Elwood 2001). At a site in Virginia, it was noted that a reduction in forest densities also leads to increased nest predation and lower bird abundance (Leimgruber et al. 1994). These results were reinforced by a study of songbird/deer population relationships in British Columbia that found a 93% decrease in bird species dependent on understory vegetation (Allombert 2005).

3.2. Invasive Species Colonization

NatureServe, an network of state natural heritage programs and a leading source for information about rare/endangered species and threatened ecosystems, defines invasive species as a non-native plant species that threatens biological diversity. Specifically invasive species are often characterized by managers as those that:

1. Are present, but not native[2], in the region of interest, and
2. Maintain themselves or recurrently appear in conservation areas or other native species habitats, and
3. Negatively affect the native species and other natural biodiversity within the region of interest, generally by outcompeting or hybridizing with native species, or by altering ecological communities or ecosystem processes (Morse et. al. 2004).

Over the past two decades invasive species have come to be recognized as one of the most serious and ongoing causes of species decline and native habitat degradation (Vitousek et al. 1997; Wilcove et al. 1998).

Invasive species often establish on sites following disturbance. The landscape of what is now the Refuge has been repeatedly disturbed since as early as the mid-17th century. Records show earlier disturbances (dike building and maintenance, and agriculture) were likely followed by establishment of native plants species (see Section 2.1). It is unclear when exactly invasive species found on the Refuge began colonization, but by 1968 the vegetation survey completed as part of *Two Studies of Tinicum Marsh* (McCormick et al. 1970) listed 11 invasive species that are still persisting today:

Common reed (*Phragmites australis*)
garlic mustard (*Allaria petiolata*)
Japanese honeysuckle (*Lonicera japonica*)
Japanese hops (*Humulus japonica*)
Japanese knotweed (*Polyganum cuspidatum*)
multiflora rose (*Rosa multiflora*)
Norway maple (*Acer platanoides*)
privet (*Ligustrum arvense*)
purple loosestrife (*Lythrum salicaria*)
reed canary grass (*Phalaris arundinacea*)
tree-of-heaven (*Ailanthus altissema*)

[2] One common exception to this criteria is common reed (*Phragmites australis*). *Phragmites* is a species native to North America. However, recent research suggests that this species has been genetically altered due to an introduction from a European genotype, making it the aggressive colonizer of wetlands that it is today (Chambers et. al. 1999, Saltonstall 2002).

However, McCormick et al. does not include five additional species noted during the Delaware Riverkeeper Network's field survey:

Bush honeysuckle (*Lonicera maackii*)
Japanese stiltgrass (*Microstegium vimeneum*)
Mile-a-minute (*Polyganum perfoliatum*)
Oriental bittersweet (*Cephalanthus orbiculatus*)
Porcelainberry (*Ampelopsis brevipedunculata*)

This suggests that these species are relatively new arrivals that have colonized only within the past 30 years.

Nearly all areas surveyed at the Refuge (except for some freshwater tidal marsh communities) were impacted to varying degrees by non-native, invasive species. In all, 16 invasive species were identified on Refuge lands. These species are prioritized for control in Section 5.4.

3.3. Alteration of Freshwater Tidal Marsh Ecosystems

As discussed in Section 2, much of the areas in and around the Refuge were historically freshwater tidal marsh. The remnant that remains is only a fraction of what once existed along the Pennsylvania coast of the Delaware River. Loss of marsh area dates back centuries, as early as the first Dutch settlements of the 1640's, when many marsh areas around the Tinicum region were diked for agriculture.

More recent losses of tidal marsh occurred between the 1950's and early 1970's, when areas referred within this plan as Hoy's Pond, Henderson Dike Area, State Road 420 East, and State Road 420 West were filled (or dredged, as was State Road 420 East and West) (see Figure 1). As a result of these large-scale disturbances, altered hydrology, invasive species introductions, and high herbivory levels continually impact many of these areas. As observed as part of Delaware Riverkeeper Network's field surveys, these areas are typically dominated by near monocultures of non-native invasive species, contain fill and debris, un-natural amounts of open water habitat, and lack proper ecosystem structure.

3.4. Lower Darby Creek Geomorphology

A Rosgen Level I and II stream classification assessment was conducted by Delaware Riverkeeper Network as part of the geomorphic analysis of Lower Darby Creek. The purpose of this assessment was to determine the morphological characteristics of streams including sensitivity to disturbance and potential for natural recovery (Rosgen 1996). Stream data such as channel slope, bed characteristics, entrenchment ratio, and sinuosity were collected and analyzed from historic (1965-1990) and more recent (2000) aerial photographs along with topographic and other maps displaying the Refuge area dating between (1757-2004).

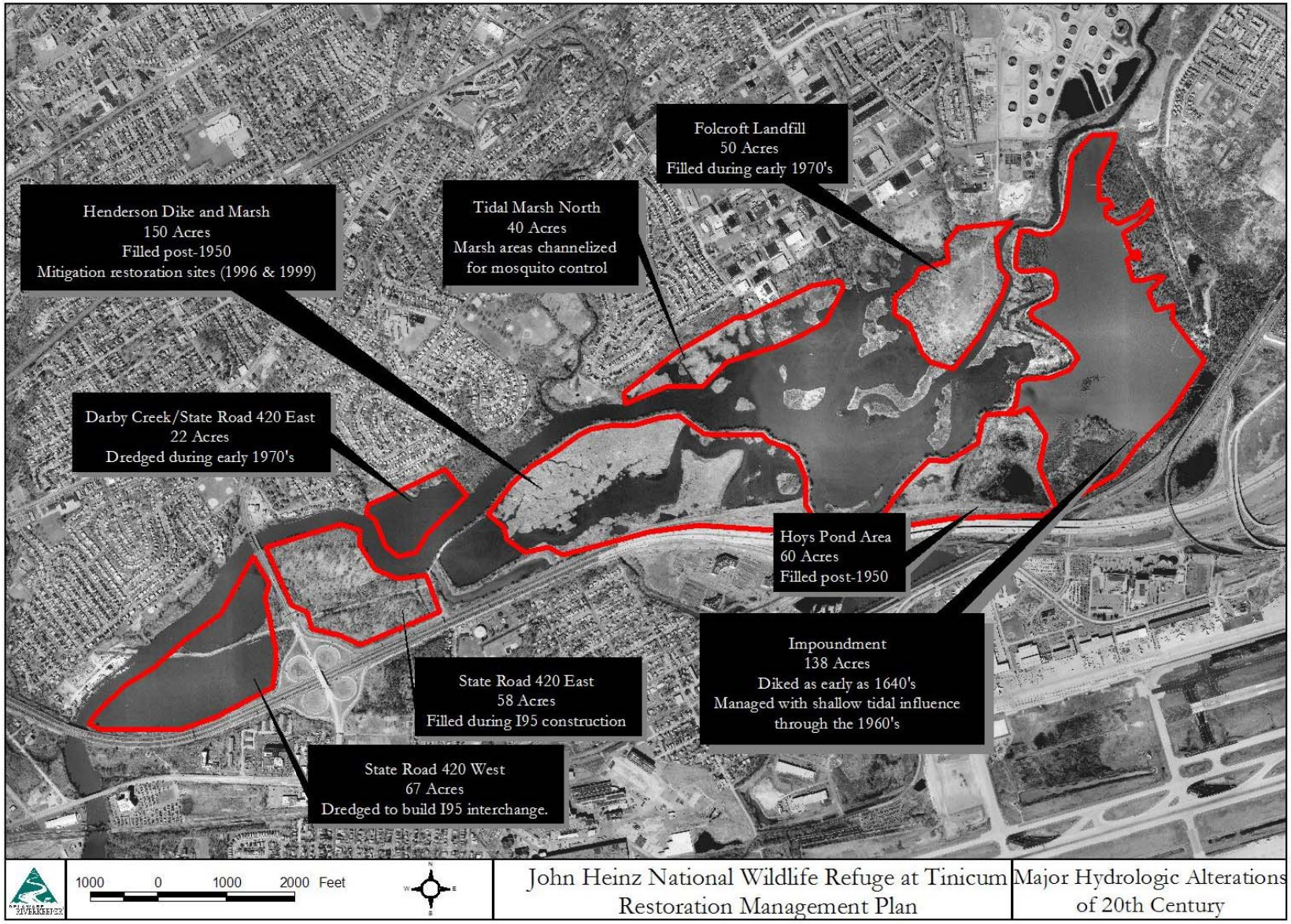
Two dominant stream channel types exist in the Refuge:

1. G6 (i.e., entrenched channels with moderate sinuosity, low bankfull width/depth ratios, and silt-dominated substrate) reaches of Darby Creek are found in areas containing diked and otherwise altered floodplains.

2. DA6 (i.e., anastomosed channels with variable sinuosity, low bankfull width/depth ratios, and silt-dominated substrate) reaches of Darby Creek are found throughout the Tinicum and Henderson marsh areas containing freshwater tidal marshes.

Waters of the Delaware Estuary tidally influence Lower Darby Creek within the Refuge. Tidal range within the Refuge is approximately 5.8 feet. Tidal streams, such as the portion of the Lower Darby throughout the Refuge, tend to have relatively stable channels when compared to

Figure 1. Major Hydrologic Alterations of the 20th Century



streams with unidirectional flows. However, major changes to the stream or watershed such as loss of vegetation, channel, alterations, urbanization, can affect stream morphology and cause the stream channel to adjust (e.g., erosion). The geomorphic assessment of Darby Creek and other tributaries within the Refuge generally reflect this inherent stability and response to major impacts.

The majority of streams within the Refuge have remained relatively stable over the past 40 years and longer. Analysis of historic aerial photographs and other maps show Hermesprota and Little Thoroughfare Creeks and portions of Darby Creek appearing relatively unchanged. However, major changes have been noted on Bow Creek and on other portions of Darby Creek. Bow Creek, which historically connected Darby Creek and the Delaware River across what is now Philadelphia International Airport, is today completely isolated from the Darby. Darby Creek itself has displayed several signs of adjustment, most notably during the 1980's. Analysis of aerial photos from 1980 and 1990 show that the multi-channeled Darby's main channel cut through the center of Tinicum marsh, shortening its total length by nearly half (from 8,400 linear feet to 4,800 linear feet). It is unclear what influenced this dramatic shift or whether the blockage of Bow Creek may have influenced this alteration of Darby Creek.

Another geomorphic influence on the Refuge is sea level rise. Elevations of freshwater tidal marshes greatly influence their structure and composition. Maintaining a diverse marsh is critically tied to factors influencing tidal elevation. Sea levels have undergone cycles of rising and falling for tens of thousands of years. The existence and prevalence of tidal marshes (both saltwater and freshwater) during periods of sea level rise has relied on their natural accretion of sediment depositing on the marsh (thus compensating for the rise in water levels) or outward migration into adjacent areas. The latter of these options is unlikely for Tinicum marsh due to the density of urbanization adjacent to the Refuge. It is unclear exactly what effect sea level rise will have on the Refuge in the future, but it is clear that the marsh's ability to respond and adapt to rising water levels has been altered and will have an impact.

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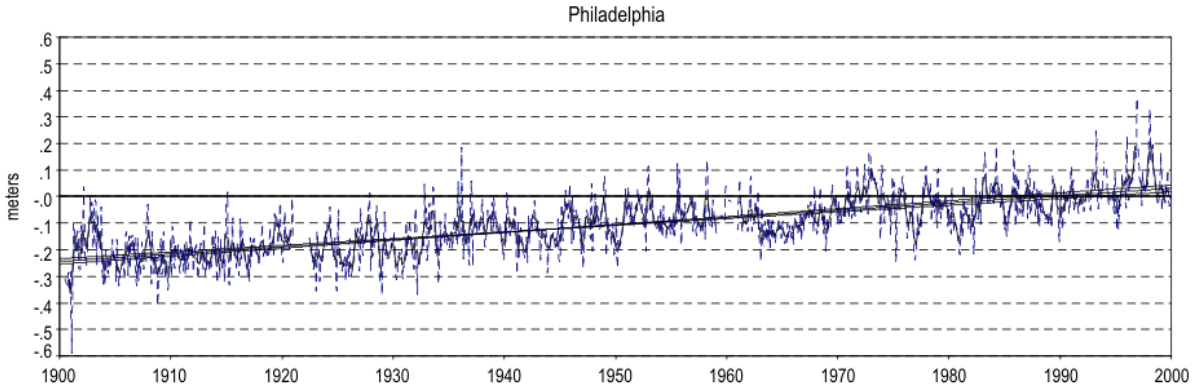
The National Oceanic and Atmospheric Administration's (NOAA) National Ocean Survey (NOS) tidal gauge data collected at Philadelphia (Figure 2) shows that sea level has risen almost a foot (0.9 feet) over the past century (NOAA/NOS 1999). This trend is expected to continue into the next century, with a projected sea level rise of one meter in the Delaware Bay by 2100 (Park et al. 1989). The effect sea level rise will have on Lower Darby Creek and the freshwater tidal marsh remains to be seen.

Figure 2. Monitored Sea Levels at Philadelphia, 1900 – 2000 (NOAA/NOS 1999)



3.5. Watershed-Based Impacts

Water quality in the Refuge is the results of the input of three major streams: Darby Creek, Cobbs Creeks (a major tributary to the Darby) and the Delaware River. The contribution from each of these sources varies depending upon tidal, hydrological, climatological and anthropogenic conditions. In other words, the water quality found in the Refuge is a highly variable and complex phenomenon.

The status of water quality and aquatic life is determined by various chemical, physical and biological parameters. Data for Darby and Cobbs Creeks have been collected by the Pennsylvania Department of Environmental Protection (PADEP), the U.S. Geological Survey USGS), the Philadelphia Water Department (PWD), Darby Creek Valley Association (DCVA), the Academy of Natural Sciences (ANS), and others. Long-term monitoring of the tidal Delaware River occurs through the Delaware River Basin Commission (DRBC) with the Delaware Department of Natural Resources and Environmental Conservation (DNREC) conducting the sampling via contract from DRBC.

The Refuge is fortunate in that various a number of reports have been produced recently that describe and summarize the status of the Darby Creek watershed based on recent data: the Darby Creek Rivers Conservation Plan (DCVA 2004), Lower Darby Creek Area 33 EPA Facility Report (NOAA 2000), and PWD's Darby-Cobbs Characterization Report (PWD 2002). The findings of interest can be summarized as follows:

1. Fish were sampled near the head of tide on both the Darby and Cobbs Creeks during low and incoming tides.
    a. Twenty-five species of fish were found at the Darby Creek site, the best site in the watershed in terms of pollution-intolerant species, species richness, catch per unit effort, and number of individuals. However, 70% of the total number of fish and 83% of the total biomass was represented by only 4 of 25 species, indicating low species diversity, but high richness, i.e., numbers of existing species (PWD 2002).
    b. Fish collected at the head of tide in Cobbs Creek showed mixed results. Twenty-five species were found and the site had the greatest species richness and catches per unit effort, as well as the second highest number of individuals found anywhere in the Darby-Cobbs drainage. However, only 2 species represented over 70% of the total fish assemblage. Over 80% of the fish collected were pollutant-tolerant, suggesting the existence of a chemical or physical problem for the Cobbs drainage area (PWD 2002).

2. Macroinvertebrate populations indicate worse conditions than those shown by fish populations. PADEP studies in the 1990's found most streams in the lower Darby Creek watershed to be "impaired." In more recent PWD studies, both Darby and Cobbs watersheds were found to have "moderately impaired" to "severely impaired" communities. The PWD report indicates that restoring healthy macroinvertebrate populations was not an option as the loss of physical habitat is too severe. An increase in the flashiness of stream flows, due to the large increase in imperviousness, is a major impediment to the restoration of aquatic life. Not only do the extreme flows remove habitat structures, such as woody debris, but they also flush some benthic insects downstream and out of the system.
3. A factor of importance to all biological communities is runoff-derived metals. Data collected during dry and wet weather indicate that cadmium, chromium, copper and zinc may meet state water quality standards during dry flows, but during wet-weather flows, violations were noted for aluminum, cooper, chromium, lead and manganese.
4. A fish advisory, for PCB contamination, was first issued for the Darby Creek watershed in 2001. The advisory suggests consumption limits for white perch, striped bass, carp, and channel catfish and recommends no consumption of American eel (PWD 2002).
5. Studies conducted by PWD with continuous oxygen monitoring over several days show that no sites in the Darby and only one site in the Cobbs violated dissolved oxygen standards[3], a good finding (PWD 2002).
6. The tidal portion of Darby Creek has received less attention than the upstream watershed areas. One can assume that cumulative effects of pollutants and problems upstream are felt downstream near and within the Refuge. Modeling by PWD suggest that the watershed upstream of the tidal Darby Creek generates annually an estimated 2,315 tons of total suspended solids; almost 9 tons of phosphorus; 780 pounds of copper; and 2.2 tons of lead. The total loads generated by the upstream watershed areas do not necessarily reach the tidal creek. Some of the load may never reach the tidal portion because it is removed through biological, chemical and/or physical processes. A simple example of this is when a white perch that has bioaccumulated copper is caught and eaten by a passing raptor (or human). However, even though only 10 or 20% of the pollutant load might make it downstream, the cumulative impact of these discharges is significant and long-term.

During the first half of the 20th century, the Delaware River in the vicinity of Philadelphia and Camden was, undoubtedly, the most polluted stretch of river in the U.S., if not the world (Albert 1988). In September 1946, no dissolved oxygen was found in this reach of the river, a "dead

[3] A phenomenon observed in urban and other settings is excessive primary productivity, i.e., algal and other plant growth. This growth is stimulated by nutrients, but also by the loss of shade where the tree canopy has been removed. Primary productivity increases dissolved oxygen during daylight hours because of photosynthesis driven by ample sunlight. At nighttime, however, photosynthesis shuts down, but algae and other plants continue to respire, a process that removes oxygen from the water column. Respiration occurs 24-hours a day, but its effect on the removal of oxygen from the water column is masked by the larger amount of oxygen returned to the water column by photosynthesis).

Excessive primary productivity results in swings in oxygen concentrations in a stream; the highest concentrations occur during the day and the lowest at night. A related, diurnal swing also occurs with pH due to carbon dioxide. If primary productivity is excessively high, the likelihood is that water quality standards for dissolved oxygen will be exceeded at night and pH standards during the day. Exceedences of dissolved oxygen and pH water quality standards result in conditions that are harmful to aquatic life.

zone" that extended for a distance of more than 20 miles. In the intervening years, a massive effort was made to cleanup the Delaware Estuary. By the mid-1980s, major reductions in nutrient pollution resulted in needed water quality improvements. The reach where Darby Creek enters the Delaware has shown substantial improvement in this regard.

For management purposes, the tidal portions of Delaware River tributaries are considered to be part of the river. Twice each day, river water enters the Darby system during high tide. In addition, various fish species freely move between Darby Creek and the Delaware River. Because of these factors, the tidal portion of Darby Creek is considered part of the Delaware River Basin Commission's Interstate Pollution Control Zone 4 (DRBC 2004). A zone-by-zone assessment of the attainment of designated water quality uses by the DRBC in 2004 indicated that Zone 4 attained its recreational designated uses, but not its aquatic life uses. Aquatic life uses, as determined by PADEP and the Pennsylvania Fish and Boat Commission were not attained because of widespread fish advisories in the river and various tidal tributaries, not including Darby Creek. These advisories are the result of contaminants found in fish, including PCBs.

3.6. Urban Environmental Impacts

The Refuge is located within highly urbanized and industrial surroundings. This makes it vulnerable to many factors that could negatively affect ecosystem health. Point source and non-point source pollution within the Darby Creek watershed and Delaware Estuary affects water quality and available food chain support for ecosystems within the Refuge. In addition, other environmental factors, such as noise generated from I-95 and Philadelphia International Airport, may adversely affect some species dependent on echolocation, including songbirds and/or frogs (Cohen and Johnson 2004).

The Folcroft Landfill, which became part of the Refuge in 1980, is part of the Lower Darby Creek Area Superfund Site, which also includes the Clearview Landfill, located just upstream of the Refuge, and four other sites within a 2 mile stretch along Darby Creek (NOAA 2000). Coordination with the EPA regarding contaminant remediation is ongoing. As a result, no restoration activities for the Folcroft Landfill are proposed in this plan. Ecological restoration plans should be coordinated with EPA upon remediation of the contamination.

The tidal Delaware River flows and ebbs through the "Delaware Estuary"[4], past the large industrial-urban Philadelphia-Camden-Wilmington metropolitan area. This reach of river contains the second largest concentration of oil-refining/petrochemical plants and the fifth largest metropolitan area in the United States (Albert 1988). Although industrial manufacturing and other heavy industries have declined in recent decades, it still remains a significant land use, especially within the reach under consideration.

The Darby Creek watershed has numerous problems, most of which can be characterized as being derived from excessive urbanization. A general finding is that the Darby's Cobbs Creek tributary has worse quality and problems than the Darby itself (DCVA 2004).

Urbanization has resulted in large amounts of impervious surface, which in turn is:

- Increasing stormwater runoff;
- Introducing various toxic metals;
- Resulting in algal-related impacts on in-steam oxygen resources;

[4] This is a misnomer as the tidal Delaware River is not an estuary in this area. In the oceanographic sense, the Delaware Bay is actually the estuary for the Delaware River.

- Decreasing groundwater infiltration;
- De-stabilizing stream banks;
- Enlarging and/or down-cutting stream channels;
- Disconnecting floodplains and stream channels;
- Impairing and decreasing biological habitats; and,
- Decreasing stream base flows.

These impairments cause biological impacts. Fish data indicate that Darby Creek has greater species diversity including some pollution intolerant species. Biometric scores suggest that the downstream reach of Darby Creek is "good," although upstream locations were "fair" or "poor". Cobbs Creek fish metrics indicate only "fair" or "poor."

4. RESTORATION GOALS AND PRIORITIZATION

4.1. Restoration Process Overview

The Society for Ecological Restoration International (SER) defines that an ecosystem, "consists of the biota (plants, animals, microorganisms) within a given area, the environment that sustains it, and their interactions." SER describes that each biota contains a set of species, which are collectively considered a biotic or ecological community. As such, ecological communities contain a variety of species with different functional roles (i.e., producers, herbivores, carnivores, nitrogen fixers, pollinators). "Ecological communities" differs from "habitats," a term that refers to components of communities that provide required conditions for specific species (SER 2004).

Addressing the degradation of ecological communities is what sets restoration apart from other types of management such as conservation or preservation, which are focused on managing or preserving specific species, habitats, or ecosystems in their current state as opposed to directing them reach a more ecologically optimal condition.

Restoration management, as set forth by this plan, is focused on restoring the functions and components of terrestrial and aquatic ecosystems where possible. Therefore, the recommendations made within this plan are made with the intention of restoring ecological communities, not just particular habitats, of the Refuge.

4.2. Priority Systems and Goals

The lands of the Refuge include a variety of ecosystems including open water, forests, grasslands, and tidal and non-tidal wetlands. Many of the Refuge's ecosystems have been degraded, damaged, or destroyed as a result of the numerous impacts previously cited, but many of these impacted ecosystems have the potential to be restored through various management actions and specific projects. Some areas, including portions of the tidal marsh, contain healthy and intact plant communities will require a more protection-focused approach. Some ecosystems contain plant communities or species of concern. Where possible, the conservation status rankings[5] have been indicated as referenced by NatureServe Explorer and the Pennsylvania Natural Heritage Program.

[5] Conservation status rankings are used to evaluate the relative imperilment of both species and ecological communities on a global, national, and state level. Designations include a number (1-5), The numbers have the following meaning 1 = critically imperiled, 2 = imperiled, 3 = vulnerable to extirpation or extinction, 4 = apparently secure, 5 = demonstrably widespread, abundant, and secure, NR = not ranked. Numbers are preceded by a letter indicating geographic scale G = Global, N = National, and S = Subnational/State) (NatureServe 2006).

Restoring a large area consisting of a variety of ecosystems, and their plant communities, is a challenging task. To minimize the time, money, and effort spent on ecosystem restoration, the Delaware Riverkeeper Network prioritized ecosystem types to focus management activities. The philosophy behind this prioritization considers the ability of an ecosystem to self-recover and how much external effort is required to promote this process.

The general restoration philosophy and prioritization for each ecosystem is outlined below. These ecosystems each contain numerous ecological communities that are described in more detail in Appendix B. While this list provides an overview of an ecosystem's priority level, on-the-ground management efforts are not necessarily proportional to the priority level. For example, management of some areas will require little more than a systematic evaluation of threats to a system. On-the-ground directives are discussed in detail for each management unit in Appendix A.

Priority System #1. Freshwater Tidal Marsh

The freshwater tidal marsh at the Refuge represents 80% of Pennsylvania's coastal wetlands. The Refuge was established primarily to protect this ecologically vital 200 acres of freshwater tidal marsh in Pennsylvania (USFWS 2006). The marsh contains some ecological communities considered state critically imperiled (S1) and globally rare (G3) and occurrences of state/federally rare, threatened, and endangered plant and animal species.

Seven freshwater tidal marsh communities[6] are included within the freshwater tidal marsh:

Ecological Community	**Conservation Status Ranking**
Atlantic Coast Wild Rice Tidal Marsh	G4; S1
Freshwater Intertidal Mudflat	G3/G4; S1
Freshwater Tidal Mixed Forbs High Marsh	GNR; S1
Nuphar lutea Tidal Marsh	GNR; SNR
Peltandra virginica - Pontederia cordata Tidal Herbaceous Vegetation	G3/G4; S1
Phragmites Dominated Marsh	GNR; SNR
Typha (angustifolia, latifolia) - (Schoenoplectus spp.) Eastern Herbaceous Vegetation	G5; SNR

Restoration recommendations for these areas include:

a. Preserve currently un-impacted and functioning systems, especially those most vulnerable to degradation.
b. Restore systems degraded by invasive species introduction, namely those affected by common reed (*Phragmites australis*) to resemble target ecological communities structure and diversity.
c. Restore systems destroyed by historic filling, dredging, and diking where feasible.
d. Prevent future encroachment of wetlands and their surrounding riparian corridor on and near the Refuge.
e. Participate in/coordinate Spill Prevention, Control, and Countermeasure Plans or other environmental emergency action plans as related to protection of open water and tidal wetlands on Refuge lands.

[6] These communities are described in more detail in Appendix B.

Priority System #2. Freshwater Non-Tidal Marsh

Many non-tidal wetlands are also found throughout the Refuge. These systems support a large number of waterfowl, fish, and other species. Some non-tidal marsh areas contain occurrences of state/federally rare, threatened, and endangered plant and animal species.

Three non-tidal wetland communities[7] are included within the Refuge:

Ecological Community	Conservation Status Ranking
Phragmites Dominated Marsh	GNR; SNR
Typha angustifolia - Hibiscus moscheutos Herbaceous Vegetation	GNR; SNR
Unidentified Wetland Community	GNR; SNR

Restoration recommendations include:

a. Restore systems degraded by invasive species introduction, namely those affected by purple loosestrife (*Lythrum salicaria*) and common reed (*Phragmites australis*) to resemble target ecological community structure and diversity.
b. Restore hydrologic function to altered systems by reconnecting historical drainage patterns, wherever feasible.
c. Prevent future encroachment of wetlands and their surrounding riparian corridor on and near the Refuge.

Priority System #3. Open Water

A variety of open water habitats are located within the Refuge including tidal river, channels, and mudflats, small ponds, and a 145-acre impoundment. Of significance are the freshwater intertidal mudflats associated with the Lower Darby Creek and tidal marshes are considered state critically imperiled (S1) and globally rare (G3). Some open water areas contain occurrences of state/federally rare, threatened, and/or endangered fish and/or animal species.

One open water community[8] is included along Darby Creek:

Ecological Community	Conservation Status Ranking
Freshwater Intertidal Mudflat	G3; S1

Restoration recommendations include:

a. Preserve natural channels and mudflats by prohibiting installation of additional piers, docks, and bank armoring on Refuge lands.
b. Support (either technically or financially) stream and riparian restoration and water quality improvements upstream of the Refuge within the Darby Creek watershed and tributaries.
c. Prohibit the recreational use of motorized watercraft within the Refuge to prevent erosion or degradation of mudflats.
d. Participate in/coordinate Spill Prevention, Control, and Countermeasure Plans or other environmental emergency action plans as related to protection of open water and tidal wetlands on Refuge lands.

[7] These communities are described in more detail in Appendix B.
[8] This community is described in more detail in Appendix B.

Priority System #4. Riparian and Upland Forests

Forests throughout the Refuge provide habitats for neo-tropical migrant birds, raptors, amphibians, reptiles, and mammal species. They also include at least one degraded plant community considered to be state imperiled (S2) and globally rare (G3) and occurrences of state/federally rare, threatened, and/or endangered plant, and/or animal species.

Nine forest communities[9] are included within the Refuge:

Ecological Community	Conservation Status Ranking
Acer negundo Forest	GNR; SNR
Acer rubrum Forest	GNR; SNR
Acer saccharinum - Acer negundo / (Elymus virginicus) Forest	G4; SNR
Acer (rubrum, saccharinum) - Fraxinus spp. - Ulmus americana Forest	G4; S1
Acer saccharinum - Ulmus americana - (Populus deltoides) Forest	G4; S3
Prunus serotina - Acer rubrum - Amelanchier canadensis - Quercus spp. Forest Alliance	GNR; SNR
Quercus palustris - Quercus bicolor - (Liquidambar styraciflua) Mixed Hardwood Forest	G3; S2
Salix nigra Temporarily Flooded Shrubland	GNR; SNR
Unidentified Forest Community	GNR; SNR

Restoration recommendations include:

a. Restore ecosystem structure through reduction of white-tailed deer herbivory pressure.
b. Restore systems degraded by invasive species introductions and other impacts to resemble target plant communities structure and diversity.
c. Restore hydrologic function to impaired seasonally flooded systems by reconnecting floodplains and historical drainage patterns, where feasible.

Priority System #5. Meadows /Grasslands

Several meadow/grassland communities at the Refuge provide habitat for neo-tropical migrant birds, raptors, amphibians, reptiles, and mammal species not associated with forested systems. While many of these areas are the result of recent disturbances (ie. utility right-of-way maintenance, facility construction) they may be restored to provide habitat diversity within the Refuge.

Two grassland communities[10] are included within the Refuge:

Ecological Community	Conservation Status Ranking
Schizachyrium scoparium - Sorghastrum nutans Herbaceous Alliance	GNR; SNR
Unidentified Meadow Community	GNR; SNR

Restoration recommendations include:

a. Maintain/enhance species composition of recent meadow restoration efforts through burning (preferred) or mowing, and introduction of additional native, non-grass, herbaceous species.
b. Restore "naturalized" areas maintained as meadows with the tilling and seeding of a mix of native herbaceous species similar to a target community.

[9] These communities are described in more detail in Appendix B.
[10] These communities are described in more detail in Appendix B.

4.3. Performance Standards Overview

As mentioned in Section 4.1, ecosystems consist of the interaction of biota and environment in a given place. In light of this, the performance standards outlined for management efforts is broken into three general categories:

1. Restoration of Community Structure: Repair, reintroduction, or re-creation of community strata lacking from an ecosystem such as canopy trees, shrubs, groundcover, vines.
2. Restoration of Community Composition: Repair, reintroduction, or management of biological aspects lacking from a community such as plant or animal species diversity and richness.
3. Restoration of Ecological Function: Repair or management of functional aspects lacking from an ecosystem such as hydrology, disturbance regime, successional processes, and providing adequate food and cover resources.

Performance standards are discussed in more detail for each restoration component and management sub unit discussed (Section 5.4).

4.4. Monitoring and Evaluation

An adequate evaluation and assessment methodology must be established prior to extensive restoration treatments and project implementation. Collection of such baseline data will provide a tool for measuring success, observe management effectiveness, and evaluate long-term trends.

Methodologies for measuring restoration effectiveness should be developed, installed, and monitored by USFWS staff with the assistance of the Friends of the Heinz Refuge or university programs. General evaluation methods recommended by the Delaware Riverkeeper Network include:

1. Monumented Vegetation Plots: Measures the change in species composition and density over time within a constant spatial area. Plot sizes and measurement systems vary depending on data collection resources. Ideally, a series of monumented plots would allow for adequate statistical representation of the entire Refuge. However, this would require intensive time and cost. At a minimum, each management unit should contain at least one monumented vegetation plot. Sampling techniques should include a structure and diversity measure, such as the Shannon Index, or techniques used at community reference sites.
2. Wildlife Surveys: Survey methods vary by target, location, and data needs and should be developed by those parties conducting the research. The Refuge has a long record of bird species observed, but this data does not provide an adequate measure of species use or changes over time. In addition, documentation of other wildlife (such as amphibians, reptiles, mammals, and insects) is necessary to provide a more complete measure of success and document response to restoration activities.
3. Fish Samplings: Restoration of fish passage and aquatic habitat should be evaluated through documented use by fish and other aquatic species. Seining or trawling can be utilized above and below fish blockages to assess populations, diversity, and size-classes both before and after restoration activities. Similar techniques can be used for marsh restoration evaluation. Lift nets or flume nets may provide better sampling of aquatic species use of marsh areas.
4. Sediment Accretion Rates: As mentioned in Section 3.5, elevations of freshwater tidal marshes greatly influence their structure and composition. Evaluating the natural accretion rates of tidal marsh areas will aid in documenting the restoration of tidal hydrology and whether or not the marsh adjusts with changes in rising tidal elevations.
5. Hydrologic Monitoring: Restoration of tidal marsh and other wetland areas highly dependent on surface hydrology should evaluate hydrology. Depending on the area and variables measured, recording measurements on staff gauges may be all that is required.

5. RESTORATION MANAGEMENT

5.1. Management Unit Overview

The ecosystem priorities, described in Section 4.2, and a guiding philosophy that encourages an ecosystem's self-recovery are taken into consideration throughout this plan. In order to identify and prioritize restoration needs at the Refuge, the Delaware Riverkeeper Network developed a system of 14 management units. These units were delineated based on several factors, such as geographic size/location, landscape influences, and existing "in-formal" designations currently in use by Refuge staff. These management units were then subdivided into sub-units based on the target ecological community identified for a particular component of that area. Management units and locations are displayed in Figure 3. Each individual management unit is profiled in Appendix A.

5.2. Unit Assessment Methodology

Delaware Riverkeeper Network Restoration Program staff assessed the ecological communities of the Refuge in the summer and fall of 2005. This assessment was focused on identifying dominant vegetation components and recording additional abiotic factors influencing the communities. Vegetation was surveyed using an assessment form adapted from a National Vegetation Classification System (NCVS) Field Data Collection Sheet previously used at the Refuge that records major ecosystem components and influences:

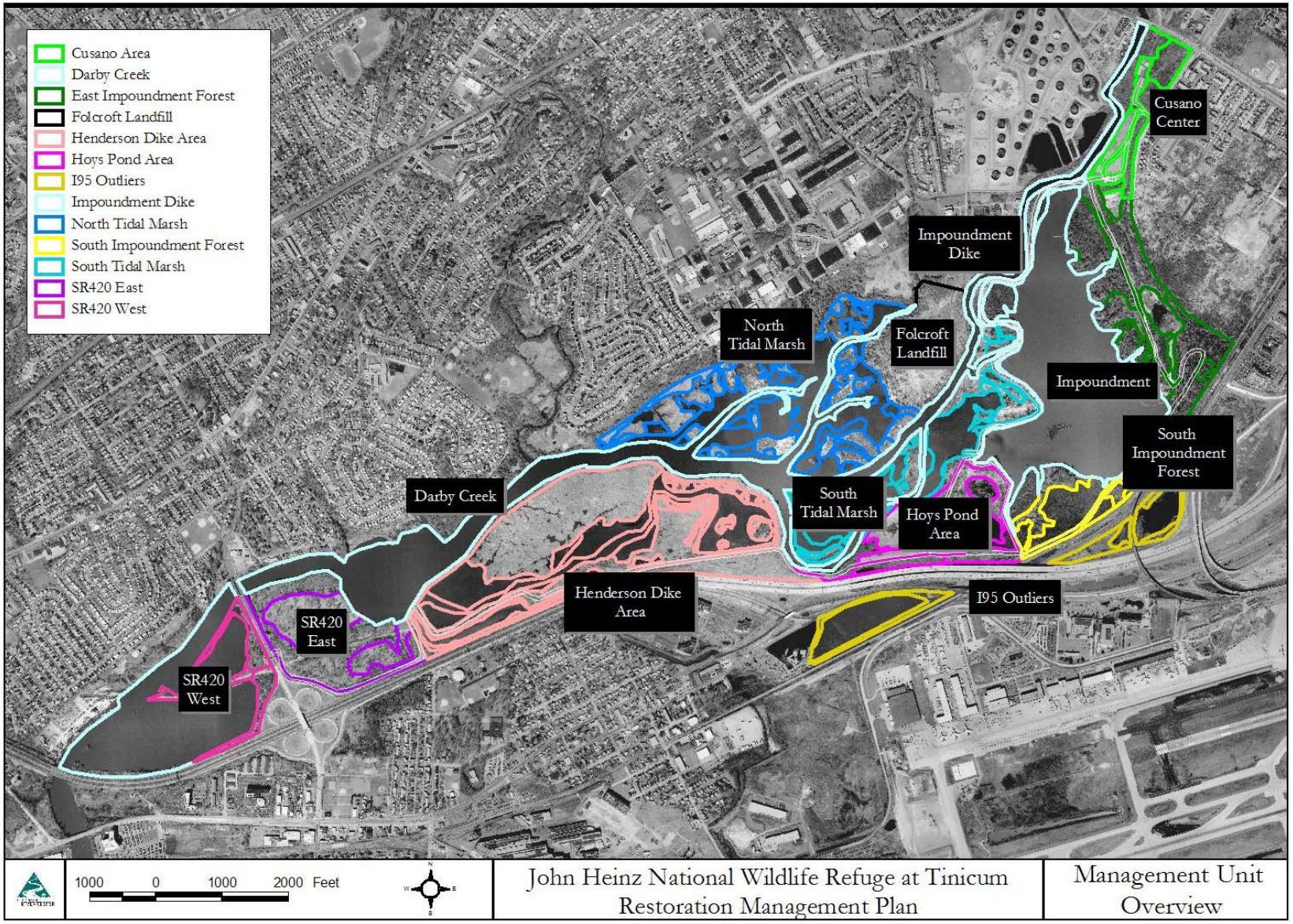
1. Environmental Conditions and Settings: Landscape and physical components affecting ecosystem processes, e.g., flooding regime, site hydrology, soil type and conditions, and surrounding land use.
2. Ecosystem Structure: Summary of physical structure of ecosystems, e.g., closed canopy forest, forest with canopy gaps, open canopy forest, early successional forest, shrub/scrub, meadow/grassland, open water, tidal marsh, and non-tidal marsh.
3. Vegetation Inventory and Relative Density: Dominant species present within ecological communities and relative densities across landscape unit area (densities of native, exotic, and invasive species were recorded using a standard visual DAFOR vegetation assessment methodology[11]).
4. Ecological Influences: Human or naturally induced ecological influences appearing to have a substantial effect on ecosystem processes: e.g., land use history, known/existing disturbance, type/extent of invasive species, animal use evidence, environmental conditions.

A copy of this assessment form has been included in Appendix F. Additional notes and the extent of vegetation types were indicated on aerial photos, topographic maps, and Refuge-generated maps used throughout the field survey.

In addition to the NVCS data sheet and mapping, additional measures were employed to complete the analysis of tidal marsh ecological systems including a marsh elevation/vegetation transect profile, and low altitude aerial photo analysis.

[11] DAFOR refers to the strata of vegetation density measured:
100>75% = Dominant, 75-50% = Abundant, 50-25% = Frequent, 25-5% = Occasional, <5% = Rare

Figure 3. Management Unit Overview



5.3. Ecological Community Identification Methodology

Data collected throughout the field surveys was compared with ecological system descriptions and data available online, through NatureServe and the Pennsylvania Natural Heritage Program (PNHP), for similar systems identified within states of the Delaware Estuary (Pennsylvania, New Jersey, Delaware). Descriptions were reviewed alongside collected field data to compare the community's occurrence along with hydrology, community structure and composition, and other influencing factors. Potential descriptions were narrowed down to individual "target community types" for each surveyed ecosystem. An overview of the ecological communities is provided in Section 4.2; descriptions of the communities are found in Appendix B.

Delaware Riverkeeper Network staff surveying the Refuge. Photo: D. Salas

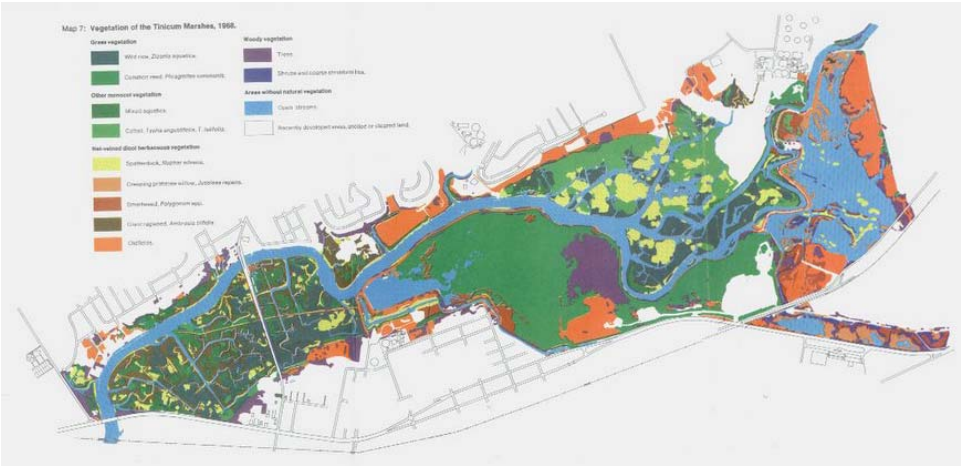
Ecological Communities of the Heinz Refuge

The data collected as part of Delaware Riverkeeper Network's field survey identified 16 plant communities the levels of association or alliance. In addition, three other communities were indicated as "unidentified" since no comparable associations or alliances were located in either NatureServe or PNHP data (see Figure 4).

Ecological Community Changes and Trends

As previously mentioned, Refuge lands have been altered in various ways throughout the area's history. The last series of major changes to what are now Refuge lands was during the early 1970's. The combined construction impacts of I-95, State Road 420's interchange, and the Corps dredging operations resulted in the filling of approximately 42 acres and the dredging of an additional 67 acres of freshwater tidal marsh. Since the early 1970's much of the landscape of the Refuge has been managed with a "hands-off" approach to successional processes at the Refuge (McManus pers. comm. 2005).

Two Studies of Tinicum Marsh (McCormick 1970) details the vegetation types present on Refuge lands in 1968. Table 1 below illustrates the changes in vegetation types between 1968 and 2005 by designated management unit.



Map of vegetation types present in 1968, Two studies of Tinicum Marsh*, 1970. McCormick.*

Figure 4. Identified Target Ecological Communities

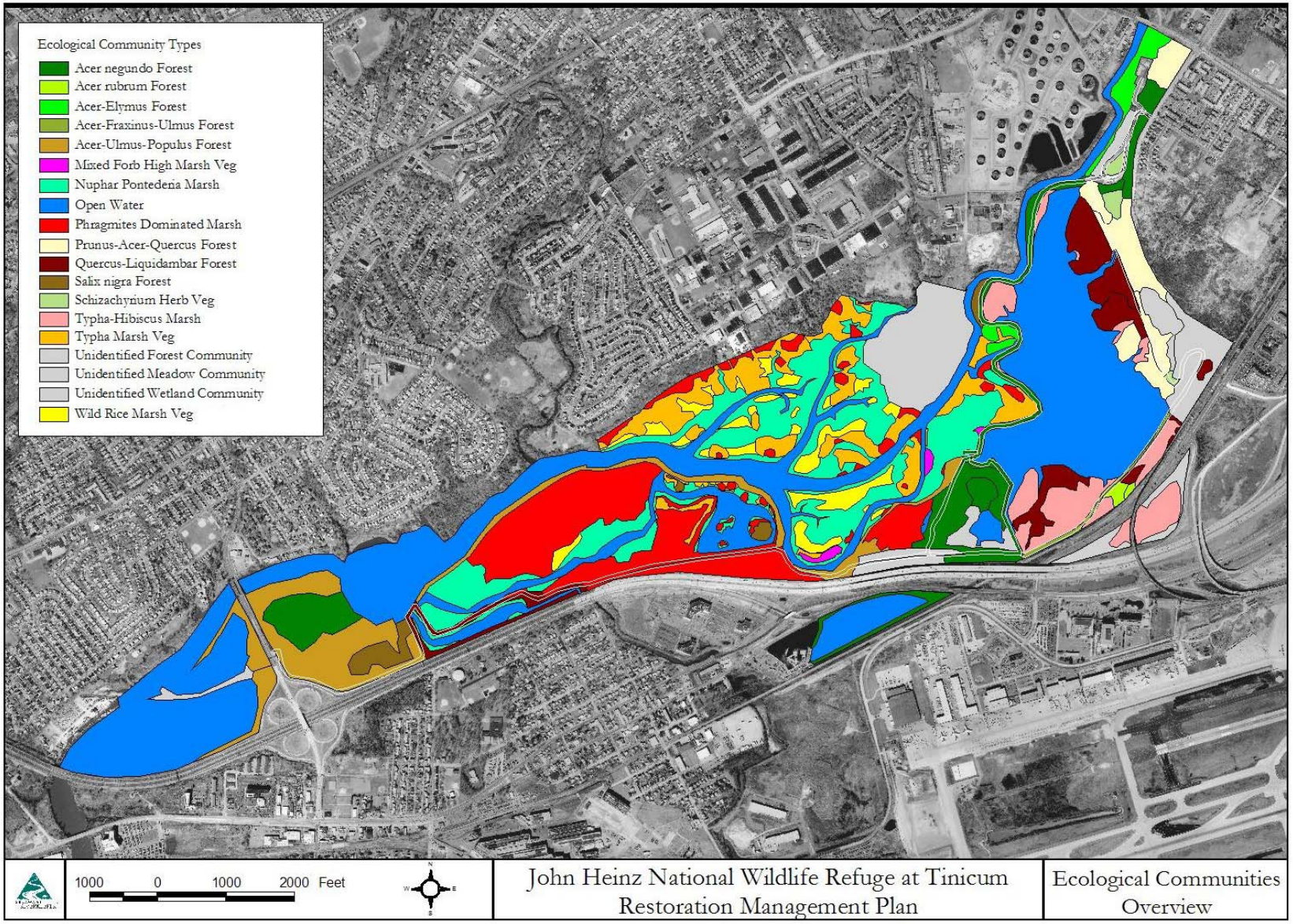


Table 1. Vegetation Comparison between 1968 and 2005

	1968	2005
Cusano Area	Data Unavailable (not included in survey)	*Acer negundo* Forest; Grassland (30%)
East Impoundment Forest	"Old Field" with some Forest (<10 %)	*Quercus-Liquidambar* Forest; *Prunus-Acer* Forest; Unidentified forest Community; Grassland (<10%)
Folcroft Landfill	"Recently developed, filled, or cleared"	Grassland
Henderson Dike Area	*Phragmites australis* marsh (>80%); "Old Field" along dike	*Phragmites australis* marsh; *Intertidal mudflat;* *Acer* Forest along dike
Hoys Pond Area	*Phragmites australis* (>70%); "Recently developed, filled, or cleared"	*Phragmites australis (<30%);* *Acer negundo* Forest; Open water
I-95 Outliers	Data Unavailable (not included in survey)	*Acer negundo* Forest; Open water
Impoundment Dike	"Old Fields"; *Typha spp.*/Primrose willow (*Jussiaea repens*) along dike edge	*Acer negundo* Forest; *Typha-Hibiscus* along dike edge
Impoundment	Open water; Primrose willow (*Jussiaea repens*); Smartweed (*Polyganum spp.*) Spadderdock (*Nuphar spp.*)	Open water; Spadderdock (*Nuphar spp.*)
South Impoundment Forest	"Old Fields"; Smartweed (*Polyganum spp.*) "Trees" (<10%)	*Acer rubrum* Forest *Quercus-Liquidambar* Forest *Typha-Hibiscus* Marsh
SR420 East	"Mixed aquatics" marsh; Giant ragweed (*Ambrosia trifidia*); *Phragmites australis* marsh; Spadderdock (*Nuphar spp.*); Cattail *(Typha spp.*); Wild rice (*Zizania aquatica*)	Open water; *Acer negundo* Forest; *Acer-Ulmus-Populus* Forest; *Salix nigra* Forest
SR420 West	"Mixed aquatics" marsh; Giant ragweed (*Ambrosia trifidia*); *Phragmites australis* marsh; Spadderdock (*Nuphar spp.*); Cattail *(Typha spp.*); Wild rice (*Zizania aquatica*)	Open water; Unidentified meadow community; *Acer-Ulmus-Physocarpus* Forest
Tidal Marsh North	"Mixed aquatics" marsh; *Phragmites australis* marsh; Spadderdock (*Nuphar spp.*); Cattail *(Typha spp.*); Wild rice (*Zizania aquatica*)	Mixed high marsh aquatic forbs; *Phragmites australis* marsh; Spadderdock (*Nuphar spp.*); Cattail *(Typha spp.*); Wild rice (*Zizania aquatica*)
Tidal Marsh South	"Mixed aquatics" marsh; *Phragmites australis* marsh; Spadderdock (*Nuphar spp.*); Cattail *(Typha spp.*); Wild rice (*Zizania aquatica*)	Mixed high marsh aquatic forbs; *Phragmites australis* marsh; Spadderdock (*Nuphar spp.*); Cattail *(Typha spp.*); Wild rice (*Zizania aquatica*)

5.4. Restoration Implementation and Management Components

The majority of recommendations put forth in this plan include management approaches focused on restoring the full potential of ecosystem structure, composition, and function on lands included in the Refuge. To achieve the recommendations, goals, and performance standards included, a variety of restoration techniques will need to be performed. While all techniques to be used cannot be anticipated or detailed, several major techniques are put forth in this plan:

Component #1: Reduce Deer Browse Impacts

Targets for Sustainable Deer Population Densities

To reduce the impact of deer browse on ecosystems, this plan recommends protecting Refuge vegetation—and those species dependent upon it—from excessive deer browse. As cited in *Deer in Pennsylvania* (Latham et. al. 2005), the intermediate disturbance hypothesis describes a bell-curve relationship between plant species diversity and frequency/intensity of natural disturbances such as fire, disease, wind damage, or heavy browsing. Under this principle, plant species diversity is maximized when there is a moderate level of disturbance; diversity decreases as disturbance becomes more or less intense.

Density levels at which a deer population is considered "ecologically sustainable" vary depending on ecosystems involved. A separate deer/songbird population relationship study in northwestern Pennsylvania concluded that the threshold level for negative effects on songbird richness was between 20 and 38 deer per square mile (deCalesta 1994). Additional research has shown a population density not exceeding 20 deer per square mile is optimal for forest regeneration. As such, in order to obtain the full potential of ecological diversity indicated, this plan recommends a goal of 20 deer per square mile as a maximum population density target for deer at the Refuge.

Mile-a-minute (Polyganum perfolatum) infesting a canopy gap at the Refuge. Photo: D. Salas

Refuge staff has conducted on-the-ground deer population surveys for several years. These surveys have been conducted by counting deer driven systematically from various portions of the Refuge. Although this method does have potential for error, such as omitting or double counting individuals (McCullough 2001), the results of these surveys consistently record population numbers in the range of 200 - 240 deer per square mile. Given that the Refuge currently covers approximately 1,000 acres (~1.5 square miles) of marsh and upland ecosystems, the Refuge's current density ranges between 133 - 160 deer per square mile. Thus a sustainable density (20 deer per square mile) for the Refuge would embody a deer population of approximately 30 individuals.

Deer Management Program Planning and Implementation Considerations

Implementing a deer management program must be incorporated into long-term management procedures. Any successful program must consider the many ecological, social, economic, and political aspects involved. A variety of techniques are available for deer management and should be thoroughly researched before planning a program.

Deer Management Performance Standards

The success of a deer management program should be evaluated through its ability to meet a series of performance standards:

1. Reduction of the existing herd to a level at or under the recommended minimum density of 20 deer per square mile within five years of the program's start.
2. Maintenance of herd levels at the target density of 20 deer per square mile for subsequent years.
3. Documented improvements in the health of deer following management efforts (including age, body weight, antler size).
4. Documented increase in diversity and/or richness of native vegetation.

Component #2: Invasive Species Control

Management Prioritization of Invasive Species

Historically, invasive species management at the Refuge consisted of control efforts targeting large populations of only a few species. This plan proposes a shift in management to address areas/species on a prioritized basis. A basic overview of the prioritization rationale is shown in Figure 5.

Figure 5. Quadrat Displaying Invasive Species Control Prioritization Rationale

High Intact Community/ High Potential for New Invasion	*Medium* Impacted Community/ Moderate Potential for New Invasion
Medium Intact Community/ Moderate Potential for New Invasion	*Low* Impacted Community/ Low Potential for New Invasion

Effective invasive species control begins with protecting intact and high quality areas first and subsequently addressing the smallest to greatest problems, thereby preventing a continuous cycle of long-term controls. Generally, the highest priority is given to the most intact communities with high potential for introduction of invasive species. Conversely, lowest priority is given to communities where the potential for new species invasions is low. Areas of low priority are often characterized by a monoculture of a single, non-native and invasive species[12].

It is important to note that a "low" priority designation does not indicate that control efforts should not be implemented in these areas. The designations of "high", "medium", and "low" are simply methods for guiding which areas should proportionally receive the most management attention.

[12] One exception to this "rule of thumb" is areas identified as either *Nuphar* or *Peltandra* dominated marshes. These areas are considered to be intact, yet due to their tidal elevation and hydrology, have a low potential for invasion.

Delaware Riverkeeper Network identified seventeen invasive species during the Refuge field survey. These species have been prioritized based on ecological impacts, the current extent of invasion, potential for spread into new areas, and the degree of difficulty involved in their control. Results of this prioritization are displayed in Table 2. The method used to prioritize invasive species was adapted from components of the Nature Conservancy's Site Weed Management Plan Template and NatureServe's Invasive Species Assessment Protocol (Morse 2004; Tu 2001).

As with prioritization of management areas (see Figure 6), species with designations of "high", "medium", and "low" are simply methods for guiding which species should proportionally receive the most management attention.

Invasive Species Control Techniques

A wealth of information on invasive species, along with their identification and control exists on various online resources. General management guidelines for specific species and links to online resources can be found in Appendix C.

Invasive Species Control Performance Standards

The success of invasive species management should be evaluated through its ability to meet performance standards:

1. Prevention of new introductions of potentially invasive species to the Refuge.
2. Continuous documented reduction in extent and relative density of non-native, invasive species in all management units.
3. Documented re-colonization of native plant species in areas where controls are implemented.

Component #3: Freshwater Tidal Marsh Restoration

Wild rice gives way to spadderdock, an elevation associated habitat transition. Photo: D. Salas

Previous and Future Tidal Marsh Restoration Considerations

To maximize the ecological potential of the Refuge landscape, this plan recommends the restoration of these altered areas back to freshwater tidal marsh. Studies of freshwater tidal marsh ecosystems have shown that marsh plant species and their associates correspond strongly to changes in marsh elevation (Odum et al. 1984; Simpson et al. 1983). As part of Delaware Riverkeeper Network's data collection at the Refuge, elevation/vegetation transect data was collected at five locations. Data collected displayed a strong relationship between elevation and vegetation (Figure 7). The implications of which are critical for restoration of tidal marsh systems.

Table 2. Prioritized List of Invasive Species

Species	Ranking	Impact	Extent	Management Difficulty	Control Priority and Focus
Mile-a-minute *Polyganum perfoliatum*	1	●	◘	○	**High** Eradicate Localized Occurrences Prevent New Introductions
Japanese knotweed *Polyganum cuspidatum*	2	●	○	●	
Porcelainberry *Ampelopsis brevipedunculata*	3	◘	○	◘	
Common Reed *Phragmites australis*	4	●	◘	●	**Medium** Reduce Size of Existing Populations Eradicate Localized Occurrences
Purple Loosestrife *Lythrum salicaria*	5	●	◘	●	
Japanese honeysuckle *Lonicera japonica*	6	●	◘	●	
Norway maple *Acer platanoides*	7	◘	◘	●	
Oriental bittersweet *Cephalanthus orbiculatus*	8	◘	◘	◘	
Japanese stiltgrass *Microstegium vimeneum*	9	●	●	◘	
Tree-of-heaven *Ailanthus altissema*	10	◘	◘	◘	**Low** Focus Primarily on Smaller Populations (<0.5 Ac) or Areas of Conservation Significance Remove as Warranted with Control of Higher Priority Species
Japanese hops Humulus japonica	11	◘	◘	◘	
Bush honeysuckle *Lonicera maackii*	12	◘	◘	◘	
Garlic mustard *Allaria petiolata*	13	●	●	●	
Multiflora rose *Rosa multiflora*	14	◘	○	◘	
Reed canarygrass *Phalaris arundicea*	15	◘	○	◘	
European privet *Ligustrum arvense*	16	○	○	○	
Mugwort *Artemesia vulgaris*	17	○	○	○	

● = High
◘ = Medium
○ = Low

Figure 6. Sub Unit Management Prioritization

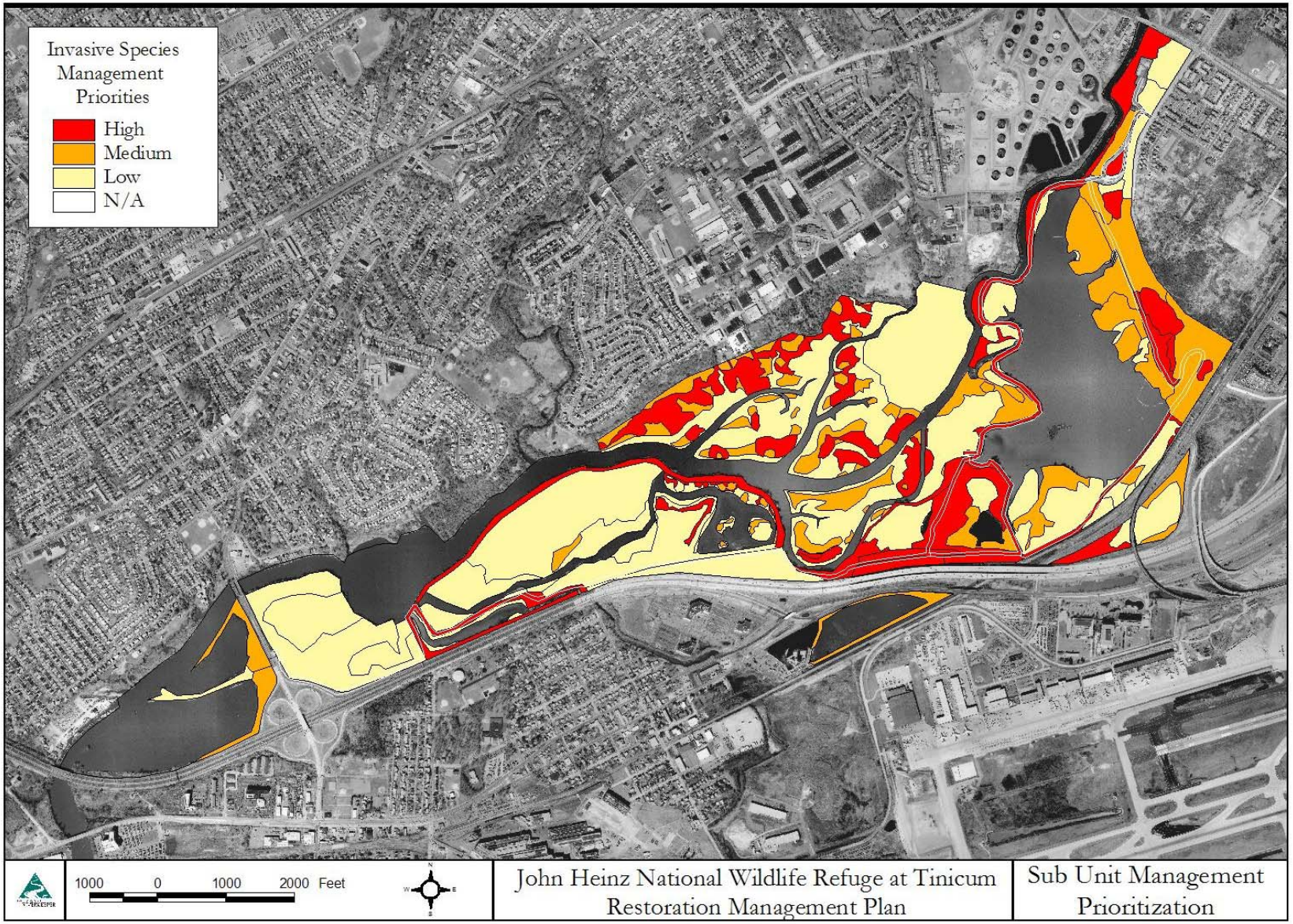
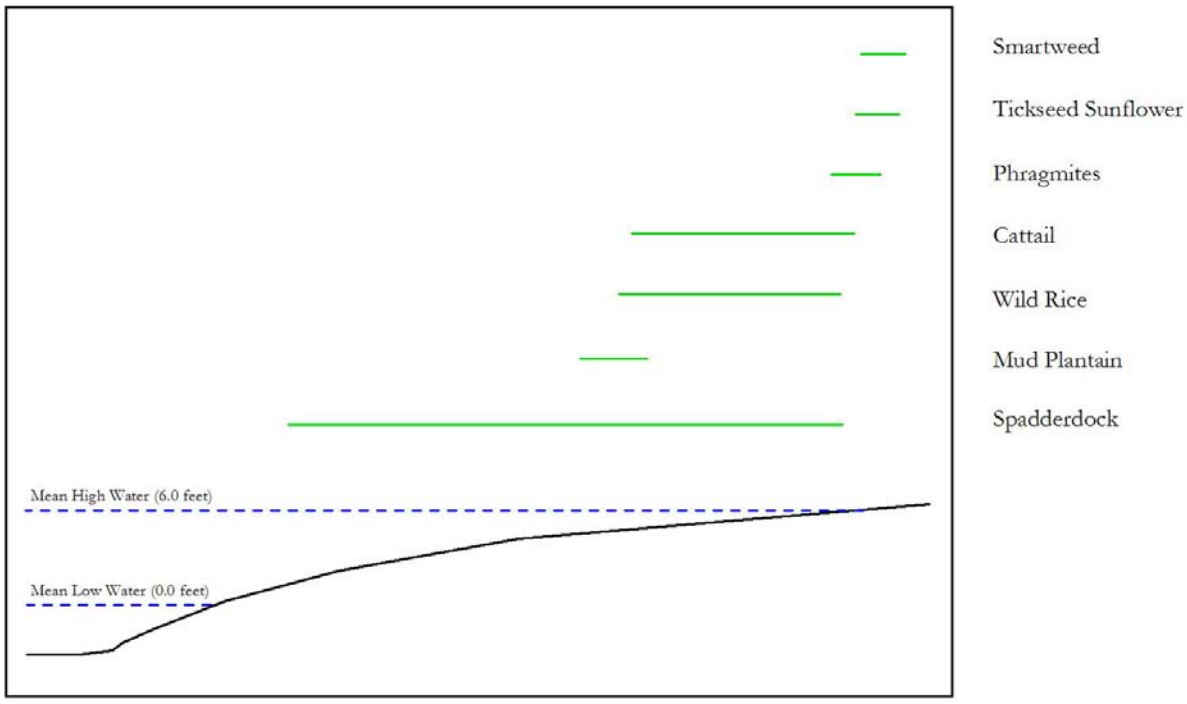


Figure 7. Relationship between Elevation and Vegetation



While the data collected are inconclusive for restoration design purposes, they do underscore the necessity for freshwater tidal marsh restoration to attain tight tolerances for achieving successful vegetation and hydrology targets. In designing future marsh restoration projects, Delaware Riverkeeper Network recommends extensive data collection of elevation and vegetation in existing "reference areas" of the Refuge's tidal marsh. Ideal reference sites display the attributes of a healthy, fully functioning, ecosystem. Data collection that can aid restoration design includes plant communities species composition and structure, along with abiotic components such as hydrology and soil information. Potential reference locations for future project design data collection include the South Tidal Marsh management unit and portions of the North Tidal Marsh unit (primarily areas surrounding Hermesprota Creek.

One previously filled area at the Refuge, the Henderson Dike Area, has been the site of two previous wetland mitigation projects[13] (completed in 1992 and 1996). While these projects have improved the quality of ecosystems in this area, they do pose additional ecological considerations:

1. 1992 Blue Route Mitigation Site: This project removed organic fill and restored tidal influence to approximately 82 acres. Monitoring reports detail healthy re-vegetation of new marsh areas with native marsh-associated species. However, in 2005 this area was over 80% dominated by *Phragmites australis*, presumably the result of either inadequate removal of sediments (marsh plain elevation is too high) or lack of marsh channels.
2. 1996 Philadelphia International Airport Mitigation Site: The latter mitigation project also removed organic fill and restored tidal influence to an additional 45 acres. Project monitoring reports were unavailable for review. In 2005, the project area was still

[13] Project designs or as-built plans for these projects were unavailable for review at the time of this writing.

significantly composed (roughly 35%) of mudflat and open water habitats. It appears that, in contrast to the 1992 site, created marsh elevations were constructed to elevations too low to support colonization by marsh vegetation.

Restoration of freshwater tidal marsh is an intensive form of restoration that can be expensive. One cost estimate has been completed for tidal restoration at the Refuge (Woodlot 2002). This estimate proposes restoration on 5 acres of previously filled marsh located in the Hoys Pond management unit (Phragmites Dominated Marsh sub unit). Complete project costs (data collection, design, permitting, construction, monitoring) estimated from $1.2 to $1.9 million (or $240,000-$380,000 per acre). While many factors influence cost (project size, location, access, sediment disposal, permitting requirements, contractual fees), this estimate is provided for planning purposes.

Tidal Marsh Restoration Opportunities

There are multiple areas suitable for tidal marsh restoration at the Refuge. Many of these areas are currently degraded and providing limited ecological services. As such, areas identified for tidal marsh restoration will require a combination of measures including sediment removal, dike breaching, marsh channel creation, and native vegetation establishment. This plan recommends that a total of 150 acres of Refuge land (see Figure 8) be restored into freshwater tidal marsh ecosystems:

1. 1992 Blue Route Mitigation Site: This 80-acre area includes the mitigation project completed ten years ago. Approximately 56 acres of this area is minimally affected by tidal influence and is dominated by *Phragmites australis*. Effective restoration of this area will require additional breaching of Henderson Dike, removal of additional sediment along with *Phragmites* root masses, and creating marsh channels and elevations similar to those found in existing reference areas of Tinicum Marsh.
2. Portions of 1996 Philadelphia International Airport Mitigation Site: Approximately 10 acres of tidal marsh restored under the 1996 mitigation project are currently dominated by *Phragmites australis*. Effective restoration of this area will likely require excavation of existing areas to remove *Phragmites* rootstock and lower the marsh plain to an elevation consistent with reference marsh areas.
3. Hoys Pond Phragmites Dominated Wetland: This 10 acre area is adjacent to Darby Creek and is also currently dominated by *Phragmites australis*. Effective restoration of this area will require breaching of the existing dike, removing sediments along with *Phragmites* root masses, and creating marsh channels and elevations similar to those found in existing reference areas of Tinicum marsh.
4. State Road 420 East: This 32 acre area was maintained as freshwater tidal marsh as recently as the 1960's. This marsh area was diked and filled during the construction of the State Road 420 Interchange along Interstate 95. This area currently contains severely impaired *Acer negundo* Forest and *Acer-Ulmus-Populus* Forest communities dominated by invasive species such as *Phragmites australis,* Japanese stiltgrass (*Microstegium vimeneum),* and mile-a-minute *(Polyganum perfoliatum).* Effective restoration of this area will require breaching of the existing dike, removing sediments along with *Phragmites* root masses, and creating marsh channels and elevations similar to those found in existing reference areas of Tinicum marsh.

5. Long Hook Creek: Long Hook Creek historically maintained a tidal connection between Darby Creek and the Delaware River. Over the 20th century, much of Long Hook Creek was buried or channelized. In an effort to reduce flooding, Tinicum Township has installed a one-way flap valve at the mouth of Long Hook Creek, which prevents natural tidal flows. The authors believe this flap valve does not adequately reduce flooding as it reduces natural streamflows and likely prevents discharge in periods of high tide. Restoring natural tidal flows to the 10 acres located on the Refuge will allow for enhanced access to fish habitat and natural hydrologic function.

Long Hook Creek outlet. Photo: D. Salas

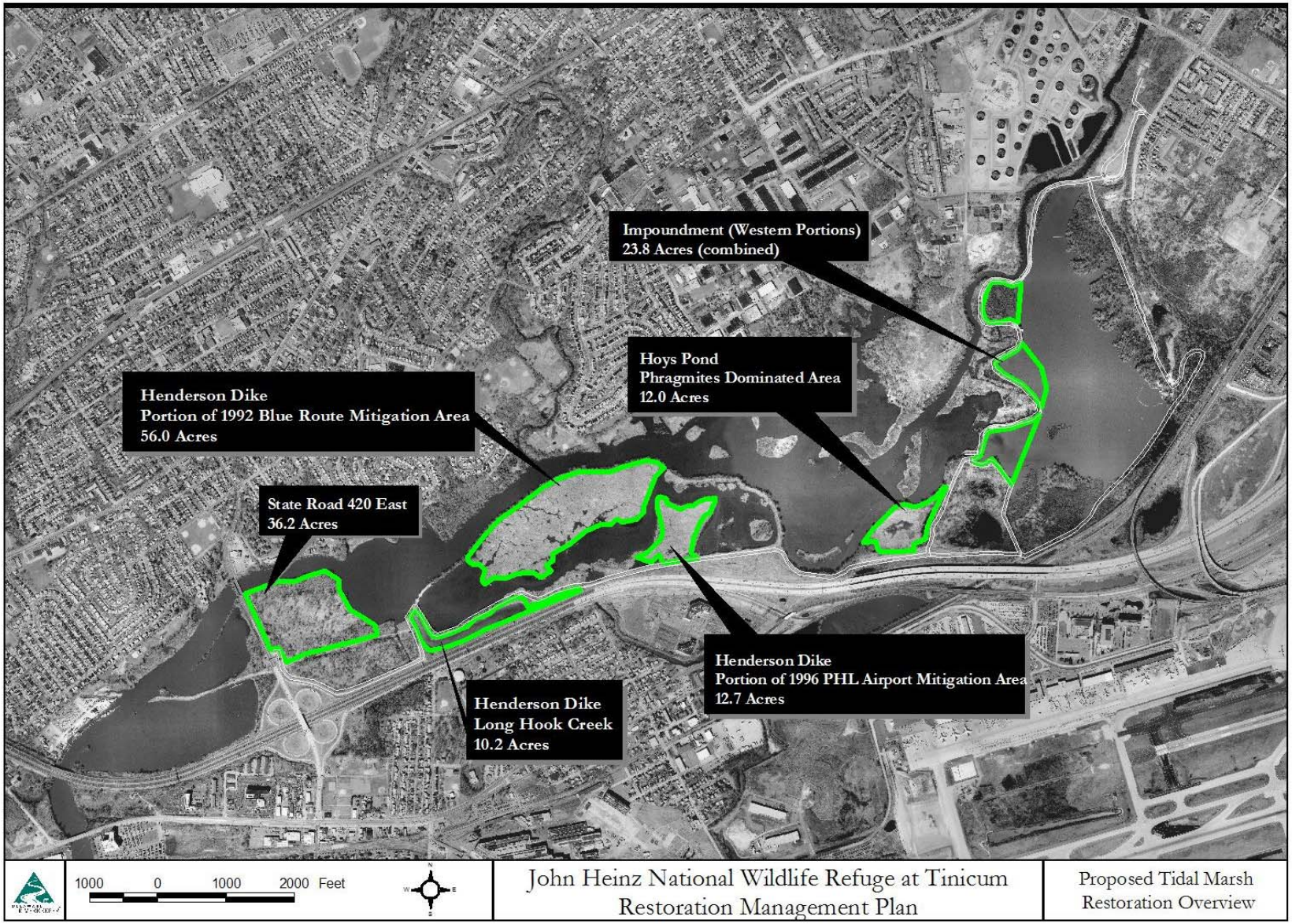
6. Impoundment: The 145 acre impoundment is a focal point for many visitors of the Refuge. However, compared to freshwater tidal marsh areas, the Impoundment provides only minimal ecological functions. Ideally, the impoundment would be removed with natural flows and freshwater tidal marshes restored throughout. But, it is highly likely the impoundment will continue in place and be actively managed to enhance habitat for shorebird and waterfowl migrations. To the extent the impoundment remains, this plan recommends restoration of at least a portion of the Impoundment into freshwater tidal marsh to provide a greater range of ecological and educational benefits.

Freshwater Tidal Marsh Restoration Performance Standards

The success of future tidal marsh restoration projects should be evaluated through their ability to meet performance standards:

1. Restoration of tidal hydrology and influence across at least 80% of the restored marsh plain (with elevations comparable to those found in existing reference areas of Tinicum marsh or another comparable reference site).
2. Documented restoration of marsh channels and their ecological function including fish passage and marsh sediment transport.
3. Establishment of native freshwater tidal marsh vegetation covering over 90% of restored marsh plain.
4. Invasive, non-native species populations limited to less than 5% of restored marsh project area.

Figure 8. Proposed Tidal Marsh Restoration Overview



Component #4: Restore Fish Passage

Fish of Lower Darby Creek and Tinicum Marsh

The Refuge provides not only beneficial terrestrial habitat, but aquatic habitat as well. Freshwater tidal marshes, like Tinicum marsh, are used by many aquatic species for spawning, year-round food and shelter, and as a nursery and rearing habitat (Mitch and Gosselink 1993). Freshwater tidal marshes are also a mixing zone for various groups of fish associated with certain habitats. Freshwater species, such as sunfish (*Lepomis spp*. and catfish (*Ictalurus spp*.), estuarine species including killifishes (*Fundulus diaphanus*) and mummichogs (*Fundulus heteroclitus*), anadramous species (including shad (*Dorosoma spp*.) and herrings (*Alosa spp*.), and the catadromous American eel (*Anguilla rostrata*) can all be found within Tinicum marsh. A list of fish species observed in similar marsh areas around the Philadelphia International Airport can be found in Appendix D.

Fish Passage Opportunities

To enhance the fish populations and their use of Refuge waters, this plan recommends implementing fish passage projects both on and off the Refuge that will benefit species using Lower Darby Creek:

1. Provide Fish Passage to the Impoundment: Historical aerial photography from the early 1960's shows the Impoundment containing defined channel systems (indicating that the Impoundment was open to regular tidal influence). As such, the Impoundment also would have provided an additional 145 acres of aquatic habitat. Although restoration of regular tidal flows to the open waters of the Impoundment is not feasible, providing fish passage through ladders or other fishways should be considered.
2. Restore Freshwater Tidal Marsh: One of the many benefits of Freshwater Tidal Marsh Restoration (Component #3 above) is providing fish passage and habitats that are currently unavailable. Implementation of the recommendations listed in Component #3 will also aid in enhancing fish populations.
3. Support Fish Passage Projects in the Darby Creek Watershed: To enhance fish populations within the Lower Darby Creek, USFWS should support, both technically and financially, fish passage projects throughout the Darby Creek watershed. Barriers to freshwater and anadramous fish, including culverts, pipes, dams, limit the available spawning and foraging habitat. Increased habitat throughout the watershed can be expected to support larger populations in Lower Darby Creek.

Fish Passage Performance Standards

Fish passage projects can be evaluated through the following performance standards:

1. The appearance of target populations in areas currently inaccessible. Specifically the ability to provide access to the following:
    a. The 145-acre Impoundment.
    b. The estimated 130 acres proposed for freshwater tidal marsh restoration.
    c. Upstream spawning habitats within the Darby Creek watershed.
2. Documented improvements in habitat quality and use of restored aquatic habitats including freshwater tidal marsh and mudflats.

Component #5: Native Plant Reintroduction

Need for Reintroduction

The landscape of the Refuge has been manipulated and altered for not just decades, but hundreds of years. In more recent decades, invasive species and excessive deer herbivory have created and exacerbated impaired ecosystems. Ecosystems often require years, or even decades, to naturally recover to pre-altered conditions (Latham et. al. 2005).

Several recent studies have shown that planting native species and certain functional groups may aid in preventing or controlling invasive species colonization. In one study, densities of garlic mustard (*Allaria petiolata*) were reduced in greater numbers where bloodroot (*Sanguria canadensis*) was planted as a follow-up to control efforts than in areas receiving no plant augmentation (Murphy 2005). Another study researched the diversity of an ecosystem's functional groups (i.e., perennial grasses, annual grasses, perennial forbs, deciduous shrub) and its role in preventing invasive species establishment. The findings of this study suggest that establishing/maintaining diversity of plant functional groups (i.e., annual/perennial grasses, annual/perennial forbs, woody trees/shrubs/vine) within a community enhances resistance to invasive species colonization (Pokorny et. al. 2005).

Therefore, re-introduction of native species may be necessary to adequately restore proper structure and composition to the ecosystems of the Refuge. The descriptions for each target ecological community provide a guide for species selection and are included in Appendix A. However, these descriptions should not be viewed as a strict species-planting list since there is some site specific and regional variation within community types.

Some of the species required for re-introduction may not be commercially available from regional native plant nurseries. Species unavailable may be contract grown by regional native nurseries depending on species needed, propagation requirements, and time/funding availability. An alternative to contract growing is establishment of an on-site nursery dedicated solely to the propagation of native plant materials needed for restoration.

Native Plant Reintroduction Performance Standards

The success of plant introductions should be measured by the following performance standards:

1. Survival of at least 80% of planted materials for a minimum of three years following installation.
2. Documentation of biological stability including successful reproduction and spread of planted population through establishment of monitoring plots.

5.5. Resource Management

The restoration of ecosystems at the Refuge requires a shift in management philosophy and long-term commitment by staff, the Friends of the Heinz Refuge, municipalities, and community volunteers to achieve success. To complete the outlined restoration components in the most sustainable, cost-efficient, and ecologically effective ways, Delaware Riverkeeper Network recommends the integration and focused application of current and future resources.

Appendix E includes a series of tables outlining opportunities for regional coordination and community involvement. These tables provide suggestions for volunteer organizations, municipalities, researchers, educational institutions, and industrial and commercial landowners.

Actions recommended in this plan can be completed through a combination of Refuge staff and community-based support. The following are major focus areas suggested for optimizing resources available to the Refuge:

Component #1: Integration of Ecological Restoration with Existing Refuge Programs

The Refuge currently employs staff with duties including law enforcement, environmental education, facilities management, biological research, and ecological management. Restoration management should not be assigned to a single position or employment description. Rather, all staff should integrate ecological restoration in their current duties. Ways to accomplish this include:

1. Invasive Species Prevention: All staff should participate in identifying new and potentially invasive, species as they occur on site or identify expansion of existing invasive species into new areas of the Refuge.
2. Volunteer Supervision: Programs including outreach and education personnel should integrate restoration activities by organizing and directing school and volunteer groups participating in restoration activities.
3. Restoration Activities: Control of invasive species, operating equipment, implementing projects, and evaluating measures of success all require investments of staff time. To the extent possible, all staff should assist in restoration practices to reduce the workload burden on any one staff member.

Component #2: Capacity Building for Support Organizations

The Refuge is not only ecologically important; it is also socially important, providing access to a natural area in a highly urban setting and important opportunities to educate the public about the benefits of native plants and wetland, upland and aquatic habitats. One key Refuge resource is the existence of volunteer-based organizations willing to provide assistance, most notably, the Friends of the Heinz Refuge. Other organizations have also conducted programs or projects at the Refuge including Darby Creek Valley Association and Center in the Park's Senior Environmental Corps. Assisting in the capacity building of these and similar organizations will aid the Refuge by securing public support for restoration management as well as volunteer participation in a variety of Refuge restoration and protection efforts. Refuge staff can support this through several actions:

Provide Facilitation and Technical Support: Assisting local and regional organizations that provide the Refuge with volunteer support will encouraging participation in those organizations. Assistance can take many forms but may include providing meeting facilities, support for projects (on and off site) that benefit Refuge resources, continuing education opportunities in restoration ecology.

Identify Organization Projects: Some actions discussed in Section 5.4 can be implemented primarily by support organizations. Manual control of the following invasive species (as directed by Refuge staff) is one important role:

- Bush honeysuckle (*Lonicera maackii*)
- garlic mustard (*Allaria petiolata*)
- Japanese honeysuckle (*Lonicera japonica*)
- Japanese hops (*Humulus japonica*)
- Japanese stiltgrass (*Microstegium vimeneum*)
- mile-a-minute (*Polyganum perfoliatum*)
- multiflora rose (*Rosa multiflora*)
- Norway maple (*Acer platanoides*)
- Oriental bittersweet (*Cephalanthus orbiculatus*)
- Porcelainberry (*Ampelopsis brevipedunculata*)
- privet (*Ligustrum arvense*)

Additional projects suitable for volunteers include native species reintroductions (including maintenance of an on-site nursery, if needed), and assistance with measures of success evaluations.

Component #3: Funding Opportunities

Using community-based and non-profit organizational leverage, the Refuge has an opportunity to obtain funding for various projects and needs referenced within this plan. The following short list includes several funding opportunities available at the time of this writing. Current opportunities include, but certainly are not limited to:

Growing Greener/Growing Greener II

Administered by the Pennsylvania Department of Environmental Protection, projects funded under this program include: watershed assessments and development of watershed restoration or protection plans; implementation of watershed restoration or protection projects (stormwater management wetlands, riparian buffer fencing and planting, streambank restoration; and demonstration/education projects and outreach activities.
General Deadline: Early March

Delaware Estuary Grants

Administered by the National Fish and Wildlife Foundation, projects funded under this program must address objectives outlined in several regional plans such as the Delaware Estuary Comprehensive Conservation and Management Plan, and Delaware River Basin Commission's Water Resources Protection Plan for the Delaware River Basin. Projects include: restoration of riparian corridors, wetlands, coastal habitats, shorebird habitats, and fish passage, watershed based planning, and volunteer-based efforts. The Foundation also has additional funding opportunities available for various habitat and species restoration goals.
General Deadline: Late May/June

Open Rivers Initiative

The National Oceanic and Atmospheric Administration's Open Rivers Initiative provides funding and technical expertise for community-driven, small dam and river barrier removals. Projects are expected to provide an economic boost for communities, enhance public safety, and improve populations of NOAA trust resources. Some NOAA trust resources are (or potentially) located on the Refuge such as striped bass, Atlantic sturgeon, American eel, American shad, and blueback herring.
General Deadline: January

Community Based Restoration Program Grants

American Rivers, with the National Oceanic and Atmospheric Administration's Community-based Restoration Program, provide financial and technical assistance for dam removal and fish passage projects in the Mid-Atlantic. Funds are provided for community-driven dam removals and fish passage projects that restore habitat of anadromous (migratory) fish.
General Deadline: Biannual in early April and early November.

Foundation Grants

In addition to the several state and federal funding sources, there are a number of local, regional, and national private foundations with funding goals dedicated to environmental protection and restoration. Each foundation has their own application and funding guidelines.
General Deadline: Varies by foundation.

Most of these programs provide funds only to 501(c)(3) organizations or municipalities. As such, these opportunities must be completed in partnership with a supporting organization such as the Friends of the Heinz Refuge and/or local municipalities.

5.6. Implementation Timeline

The restoration of ecosystems at the Refuge will require a long-term commitment by USFWS staff and the Friends of the Heinz Refuge. Below is a timeline (Table 3) that displays the general phasing of restoration work and evaluation of its success. In addition, short-term and long-term actions are discussed in more detail for each management unit in Appendix A. Specific timeframes will depend on funding and workload availability.

6. CONCLUSION

The John Heinz National Wildlife Refuge at Tinicum is an important ecological treasure to the region and the Delaware River. The Refuge provides a wide variety of important habitats that support birds, mammals, reptiles, amphibian, and aquatic life. The Refuge provides flood control, drought control and water quality benefits to the Delaware River watershed by absorbing and infiltrating rainfall and stormwater while at the same time capturing and filtering out pollution. Perhaps most importantly, the Refuge provides an increasingly unique opportunity for urban communities to enjoy nature and the river – through the appreciation of the natural world. As a result, the level of community participation and environmental protection of the region will grow and strengthen.

These recommendations have been provided to assist the formal Comprehensive Conservation planning process the Refuge will shortly undertake. By assessing and characterizing the ecosystems and their relationships, the Delaware Riverkeeper Network hopes that this plan will focus future management on the protection and restoration of this important resource of the Delaware River and the Philadelphia Region.

The Delaware Riverkeeper Network values the Refuge for the important ecological system it is, and we value all those, particularly the Friends of the Heinz Refuge and the U.S. Fish and Wildlife Service who work so hard to protect it.

Table 3. Implementation Timeline

Organization	Period/Restoration Management Component		
	2006 – 2010	2011 – 2015	2016 – 2020
USFWS	- Monitor and prevent future impacts that could potentially harm Refuge ecology.	- Monitor and prevent future impacts that could potentially harm Refuge ecology.	- Monitor and prevent future impacts that could potentially harm Refuge ecology.
	- Establish restoration evaluation locations and protocols.	- Evaluate status of achieving/working toward performance standards.	- Evaluate accomplishment of performance standards.
	- Conduct annual monitoring of performance standard criteria.	- Continue annual monitoring of performance standard criteria.	- Evaluate effectiveness of the deer management program.
	- Explore deer management options and implement program.	- Evaluate effectiveness of/and continue deer management program.	- Evaluate effectiveness of invasive species control efforts.
	- Target invasive species control efforts on priority species and areas.	- Evaluate effectiveness of invasive species control efforts.	- Re-evaluate priority species for control.
	- Pursue restoration of freshwater tidal marsh and fish passage.	- Re-evaluate priority species for control.	- Complete/evaluate restoration of freshwater tidal marsh and fish passage.
	- Initiate local and regional contacts to develop management partnerships.	- Implement restoration of freshwater tidal marsh and fish passage restoration projects. - Maintain management partnerships on the Refuge and in the Darby Creek watershed and Philadelphia region.	- Maintain management partnerships on the Refuge and in the Darby Creek watershed and Philadelphia region.
Friends of the Heinz Refuge	- Develop long-term organizational vision.	- Re-evaluate organizational vision (2011).	- Evaluate accomplishment of performance standards.
	- Build volunteer and membership capacity.	- Assist USFWS in monitoring evaluation criteria.	- Assist USFWS in monitoring evaluation criteria.
	- Assist USFWS in establishing evaluation locations and protocols.	- Assist USFWS in continuing invasive species control.	- Assist USFWS in continuing invasive species control.
	- Develop invasive species control team.	- Help generate partnerships on the Refuge and in the Darby Creek watershed and Philadelphia region.	- Help generate partnerships on the Refuge and in the Darby Creek watershed and Philadelphia region.
	- Assist USFWS in invasive species control. - Help generate partnerships on the Refuge and in the Darby Creek watershed and Philadelphia region.	- Assist in securing funding for restoration projects and ecological research.	- Assist in securing funding for restoration projects and ecological research.

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APPENDIX A

MANAGEMENT UNIT PROFILES

Section 5.1 describes the need for delineating spatial areas for categorizing and defining management activities at the Refuge. This Appendix provides an overview of each specific management unit defined, special features, restoration obstacles, and a general management action strategy and timeline.

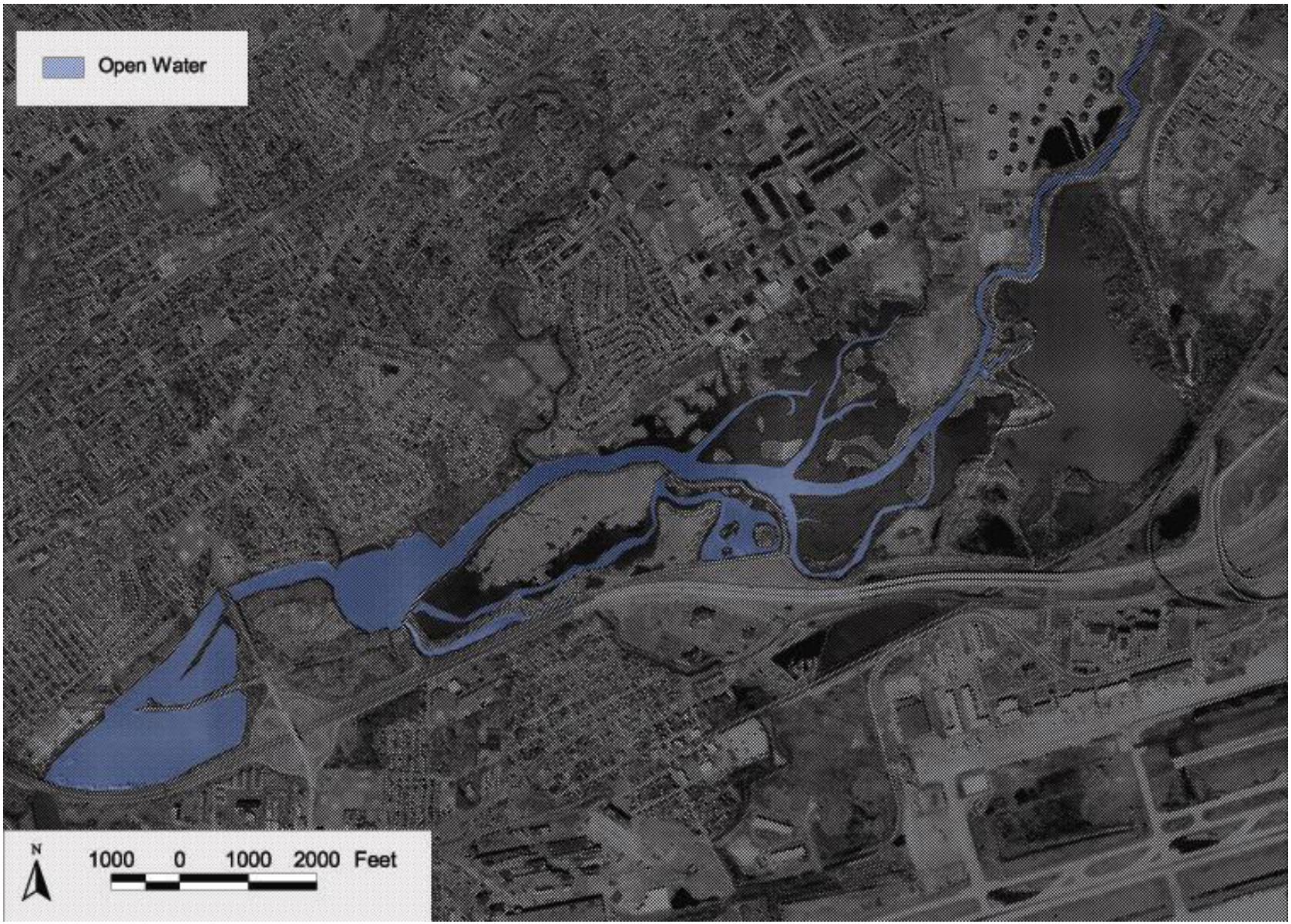
Management Unit **Page**

Management Unit: Cusano Area

Management Unit: Cusano Area

Ecological Components	Special Features	Management Priority Ranking	Restoration Obstacles	Short Term Actions	Long Term Actions
Upland Forests	Includes riparian forests adjacent to Darby Creek and public facilities. Many areas include concrete debris and fill.			• Establish vegetation monitoring plots and record baseline data for performance standards documentation. • Control invasive species introductions focusing on the priority species (Ampelopsis brevipedunculata) and as identified on Table 2 Prioritized List of Invasive Species in priority areas (identified above). • Focus native plant reintroductions in areas with poor stability, inadequate species diversity or composition, canopy gaps or other edge areas.	• Collect data annually at vegetation monitoring plots and record baseline data for performance standards documentation. • Conduct biannual (May and August) search and control efforts to prevent new colonization of invasive species. • Continue invasive species control. • Monitor sub units for new invasive arrivals, including plants, insects, and other pathogens. • Native species re-introduction as needed to reach community diversity, structure, and function targets. • Reduce excessive deer browse. • Restore 7 acres of native meadow plant communities in areas named Unidentified Meadow Community. • Remove concrete, trash, and other debris as necessary to restore natural groundlayer structure.
Acer negundo Forest		Low	Invasive species: Ailanthus altissema, Allaria petiolata, Cephalanthus orbiculatus, Lonicera japonica, Polyganum cuspidatum, Polyganum perfoliatum Excessive deer browse.		
Acer saccharinum - Acer negundo / (Elymus virginicus) Forest		High	Invasive species: *Ailanthus altissema, Allaria petiolata, Ampelopsis brevipedunculata*, Lonicera japonica, Lythrum salicaria, Rosa multiflora* *High Priority: only population present on Refuge. Excessive deer browse.		
Prunus serotina - Acer rubrum - Amelanchier canadensis - Quercus spp. Forest Alliance		Low	Invasive species: *Acer platanoides, Allaria petiolata, Cephalanthus orbiculatus, Lonicera japonica, Lonicera maackii* Forest groundlayer altered by previous fill activities.		
Grasslands/Meadows	Meadows maintained as cool season grasses.				
Unidentified Meadow Community		Medium	Invasive species: *Lythrum salicaria, Phragmites australis, Polyganum perfoliatum, Rosa multiflora* Annual mowing prevents natural succession as part of management. Consider restoration of native warm season grasses and forbs.		
Schizachyrium scoparium - Sorghastrum nutans Herbaceous Alliance	Warm season grass meadow restored during parking lot expansion.	High	Invasive species: *Artemesia vulgaris, Lonicera japonica, Lythrum salicaria*		

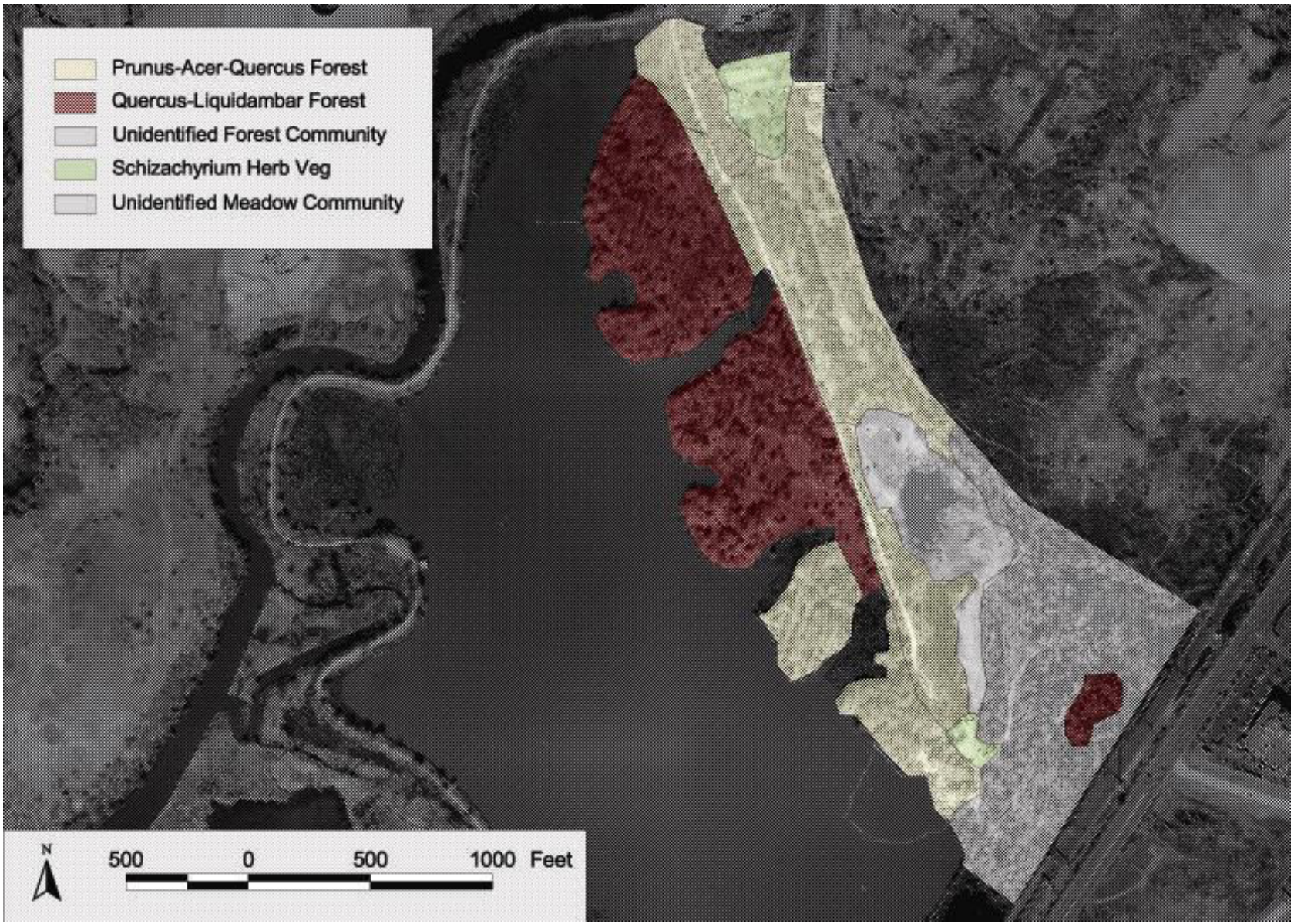
Management Unit: Darby Creek



Management Unit: Darby Creek

Ecological Components	Special Features	Management Priority Ranking	Restoration Obstacles	Short Term Actions	Long Term Actions
Open Water	Includes tidal channels and mudflats associated with Darby Creek and Hermesprota Creek.			• Conduct biannual search and control effort to prevent new colonization of aquatic invasive species. • Monitor for new invasive arrivals, including aquatic plants, insects, fish and other pathogens. • Continue involvement in Folcroft Landfill RI/FS process and develop protection and monitoring objectives for the landfill closure.	• Participate/coordinate Spill Prevention, Control, and Countermeasure Plans or other environmental emergency action plans as related to protection of open water and tidal wetlands on Refuge lands. • Prohibit the recreational use of motorized watercraft within the Refuge to prevent erosion or degradation of mudflats. • Support (either technically or financially) stream and riparian restoration and water quality improvements upstream of the Refuge within the Darby Creek watershed and tributaries. • Preserve natural channels and mudflats by prohibiting installation of additional piers, docks, and bank armoring on Refuge lands. • Explore restoration of tidal influence and/or fish passage to Long Hook Creek.
Darby Creek		High	Watershed influences such as stormwater-based pollution and impacts associated with two superfund sites located upstream. Barriers to fish passage (both on the Refuge and upstream) prevent spawning access and habitat availability to aquatic species. Wake generating watercraft may cause bank erosion and disrupt shallow aquatic habitats. Sea level rise may potentially impact Darby Creek through loss of marsh ecosystems, increased erosion, and altered morphology.		
Freshwater Intertidal Mudflat		High	Watershed influences such as stormwater-based pollution and impacts associated with two superfund sites located upstream. Wake generating watercraft may cause bank erosion and disrupt shallow aquatic habitats. Sea level rise may potentially impact mudflats through loss of marsh ecosystems, increased erosion, and altered morphology.		

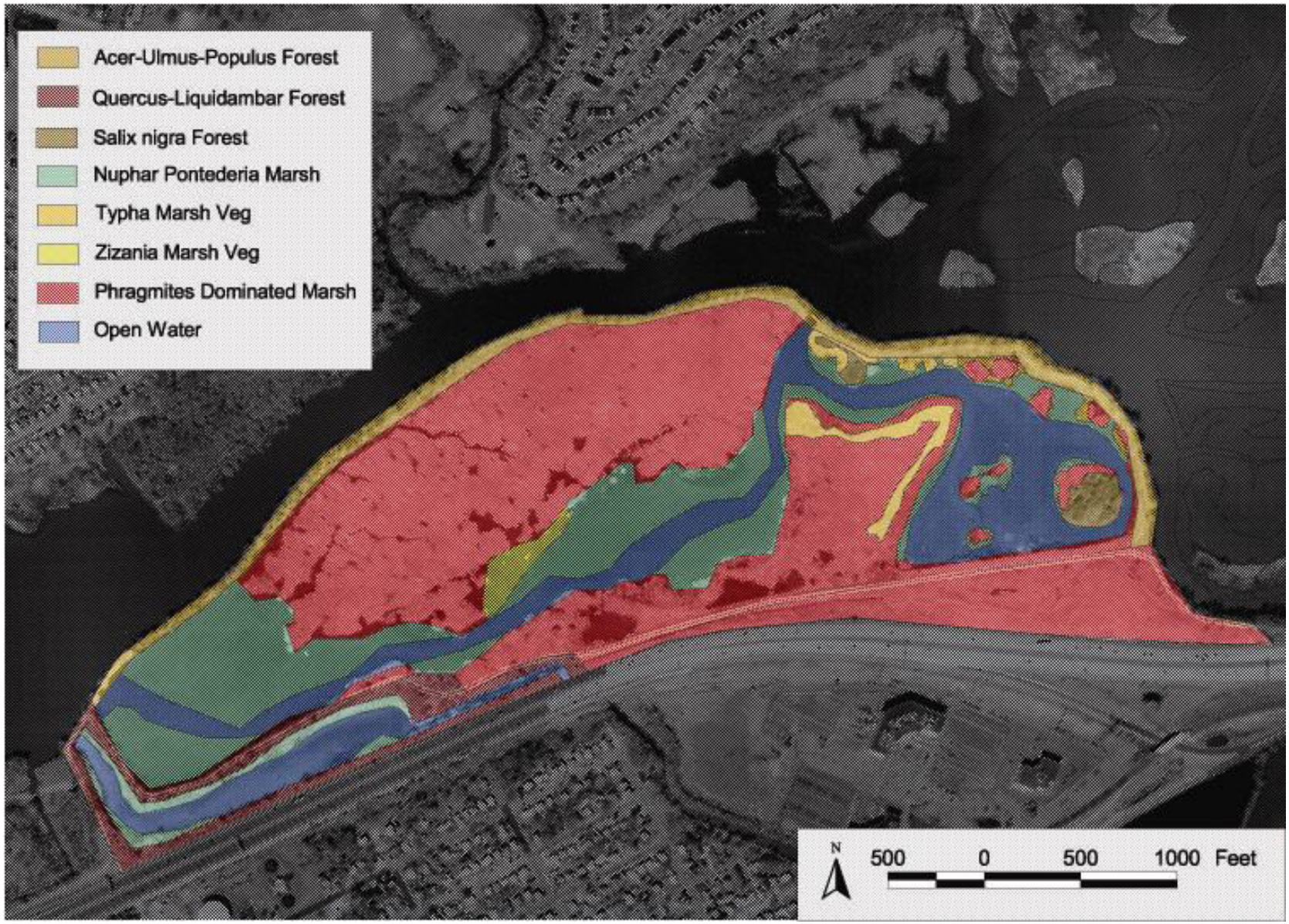
Management Unit: East Impoundment Forest



Management Unit: East Impoundment Forest

Ecological Components	Special Features	Management Priority Ranking	Restoration Obstacles	Short Term Actions	Long Term Actions
Forests	Early successional forest (<40 years old). Includes riparian forests adjacent to the Impoundment.			• Establish vegetation monitoring plots and record baseline data for performance standards documentation. • Control invasive species introductions focusing on the priority species as identified on Table 2 Prioritized List of Invasive Species in priority areas (identified above). • Prevent regeneration of gray poplar (*Populus x canescans*) in area named Unidentified Forest Community. Continue to allow regeneration of similar species: bigtooth aspen (*Populus grandidentata*). • Create partnerships with adjacent landowners to control invasive species and establish maintenance agreements on lands and right-of-ways adjoining the management unit. • Focus native plant reintroductions in areas with poor stability, inadequate species diversity or composition, canopy gaps or other edge areas.	• Collect data annually at vegetation monitoring plots and record baseline data for performance standards documentation. • Conduct biannual (May and August) search and control efforts to prevent new colonization of invasive species. • Continue invasive species control. • Monitor sub units for new invasive arrivals, including plants, insects, and other pathogens. • Reintroduce native species as needed to reach community diversity, structure, and function targets. • Reduce excessive deer browse.
Prunus serotina - Acer rubrum - Amelanchier canadensis - Quercus spp. Forest Alliance		Medium	Invasive species: *Ailanthus altissema, Allaria petiolata, Lonicera japonica, Microstegium vimeneum, Phragmites australis, Polyganum perfoliatum.* Excessive deer browse.		
Quercus palustris - Quercus bicolor - (Liquidambar styraciflua) Mixed Hardwood Forest		Medium/High	Invasive species: *Allaria petiolata, Lonicera japonica, Microstegium vimeneum, Polyganum perfoliatum, Rosa multiflora.* Excessive deer browse.		
Unidentified Forest Community		Medium	Invasive species: *Ailanthus altissema, Allaria petiolata, Artemesia vulgaris, Cephalanthus orbiculatus, Lonicera japonica, Lonicera maackii, Microstegium vimeneum, Polyganum perfoliatum, Rosa multiflora.* Excessive deer browse. Canopy regeneration dominated by gray poplar (*Populus x canescans*) seedlings.		
Grasslands/Meadows	Wet meadow maintained with shallow hydrology and temporary open water. Warm season grass meadow restored during oil spill mitigation.				
Unidentified Meadow Community		High	Invasive species: *Phragmites australis, Polyganum perfoliatum.*		
Schizachyrium scoparium - Sorghastrum nutans Herbaceous Alliance		High	Invasive species: None present at time of field survey.		

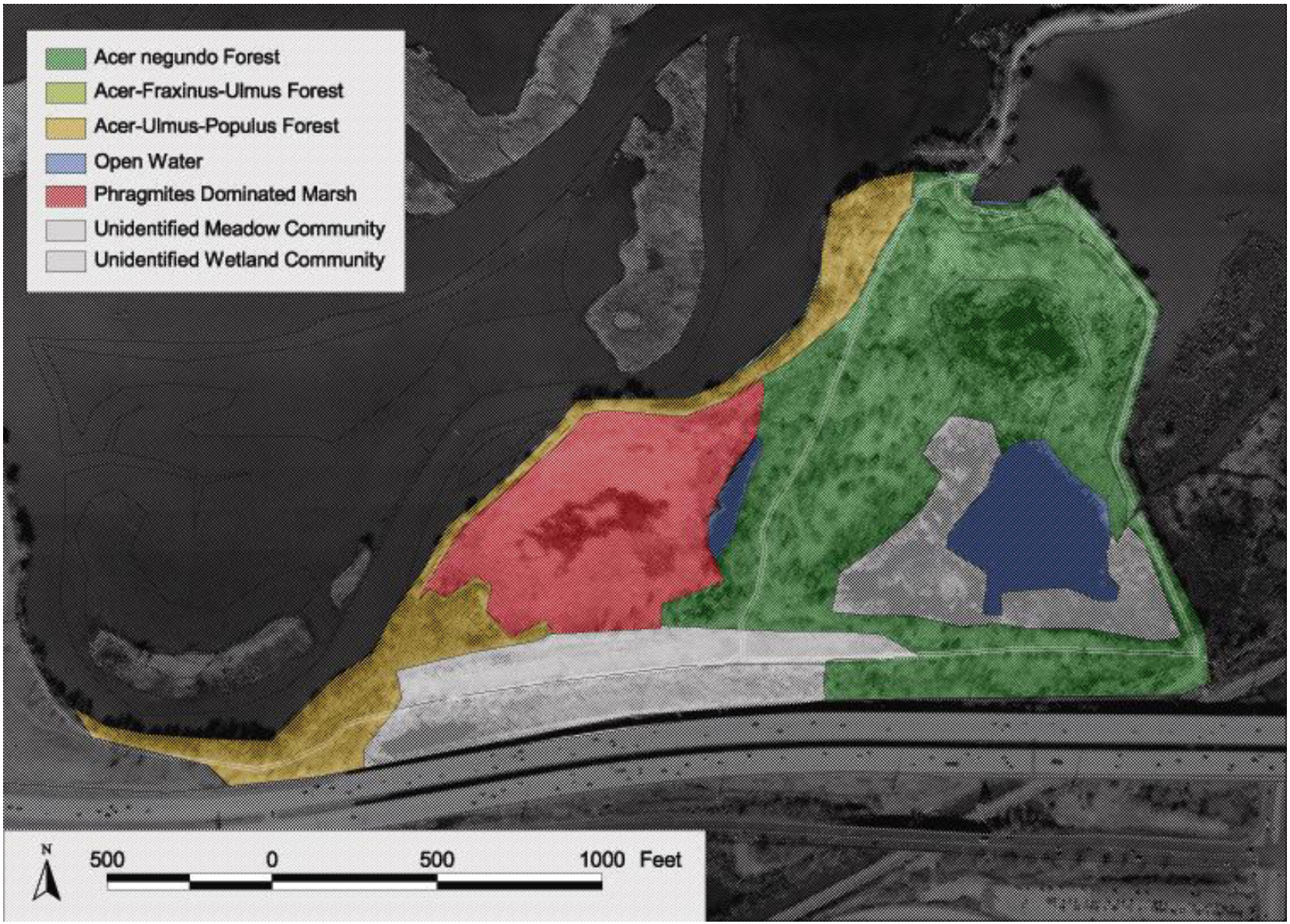
Management Unit: Henderson Dike and Marsh



Management Unit: Henderson Dike and Marsh

Ecological Components	Special Features	Management Priority Ranking	Restoration Obstacles	Short Term Actions	Long Term Actions
Freshwater Tidal Marsh	Ecological communities are highly dependent on marsh elevation.			• Preserve currently stable and functioning systems, especially those most vulnerable to degradation. • Establish vegetation monitoring plots and record baseline data for performance standards documentation. • Establish sediment accretion monitoring plots. • Control invasive species introductions focusing on *Phragmites australis* and other invasive species as prioritized on Table 2 in priority areas (identified above). • Conduct biannual (May and August) search and control effort to prevent new colonization of invasive species. • Involve adjacent property owners (Pipeline, Airport, PennDOT) that are not currently managing invasive species.	• Collect data annually at vegetation monitoring plots and record baseline data for performance standards documentation. • Collect sediment accretion data annually to assess marsh response to changing sea level elevations. • Continue invasive species control. • Monitor sub units for new invasive arrivals, including plants, insects, and other pathogens. • Create partnerships with adjacent landowners to control invasive species and establish wetland buffers in areas and right-of-ways adjoining the marsh through maintenance agreements or incentives. • Continue involvement in Folcroft Landfill RI/FS process and develop marsh protection and monitoring objectives for the landfill closure. • Explore/Implement tidal marsh restoration projects in areas currently dominated by *Phragmites* due to lack of adequate tidal influence.
Nuphar lutea Tidal Marsh		Low	Tolerance of tidal inundation makes this community resistant to known aquatic invasive species.		
Peltandra virginica - Pontederia cordata Tidal Herbaceous Vegetation		Low	Tolerance of tidal inundation makes this community resistant to known aquatic invasive species.		
Typha (angustifolia, latifolia) - (Schoenoplectus spp.) Eastern Herbaceous Vegetation		High	Potential for invasive species colonization by *Phragmites australis*.		
Atlantic Coast Wild Rice Tidal Marsh		Medium	Potential for invasive species colonization by *Phragmites australis*.		
Phragmites Dominated Marsh		Low/ Medium (populations less than ¼ acre)	Elevations in expansive areas favor *Phragmites*. Areas should be excavated to elevations similar to reference marsh areas.		
Open Water	1996 Airport mitigation project created large areas of mudflat habitat.				
Darby Creek		High	Henderson Dike may limit natural channel morphology.		
Freshwater Intertidal Mudflat		High	Henderson Dike may limit natural sediment accretion.		
Forests	Forests limited to Henderson Dike and surrounding riparian areas along access roads.				
Acer saccharinum - Ulmus americana - (Populus deltoides) Forest		High	Invasive species: *Ailanthus altissema, Cephalanthus orbiculatus, Lonicera japonica, Lythrum salicaria, Phragmites australis, Polyganum cuspidatum*. Much of the dike is inaccessible to motorized vehicles.		
Quercus palustris - Quercus bicolor - (Liquidambar styraciflua) Mixed Hardwood Forest		High	Invasive species: *Cephalanthus orbiculatus, Lonicera japonica, Phragmites australis, Polyganum cuspidatum*. Excessive deer browse.		
Salix nigra Temporarily Flooded Shrubland		High	Invasive species: *Lonicera japonica, Lythrum salicaria, Phragmites australis.*		

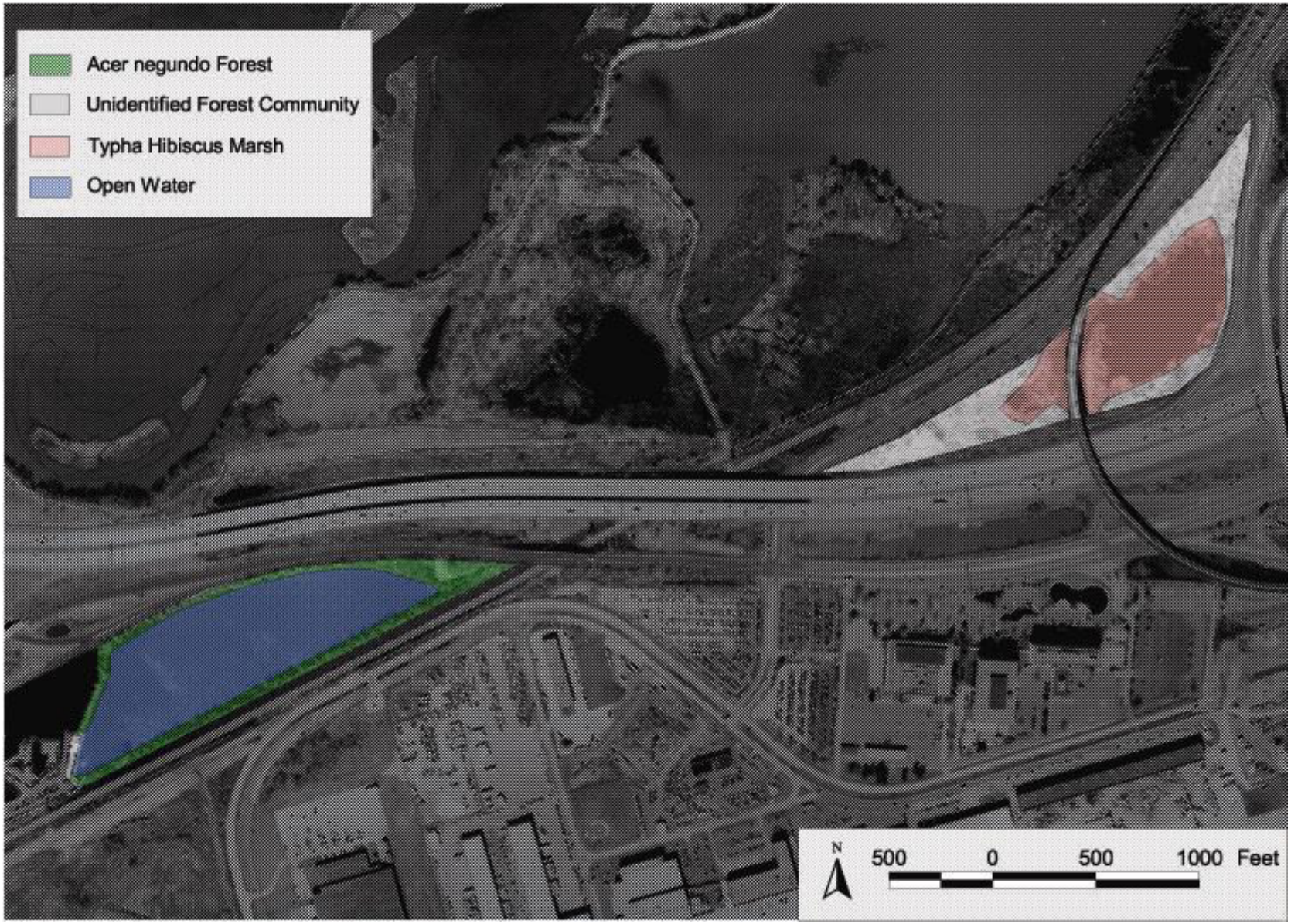
Management Unit: Hoys Pond Area



Management Unit: Hoys Pond Area

Ecological Components	Special Features	Management Priority Ranking	Restoration Obstacles	Short Term Actions	Long Term Actions
Freshwater Non-tidal Wetland	Systems potentially support state/federal species of concern.			• Establish vegetation monitoring plots and record baseline data for performance standards documentation. • Control invasive species introductions focusing on priority species as identified on Table 2 Prioritized List of Invasive Species in priority areas (identified above). • Focus native plant reintroductions in areas with poor stability, inadequate species diversity or composition, canopy gaps or other edge areas. • Install deer exclosures in high value areas where rare, threatened, or endangered species are present.	• Collect data annually at vegetation monitoring plots and record baseline data for performance standards documentation. • Conduct biannual (May and August) search and control efforts to prevent new colonization of invasive species. • Continue invasive species control. • Monitor sub units for new invasive arrivals, including plants, insects, and other pathogens. • Native species re-introduction as needed to reach community diversity, structure, and function targets. • Reduce excessive deer browse. • Restore 12 acres of freshwater tidal marsh and fish passage to suitable areas identified within the Hoys Pond area. • Restore forest hydrology to impaired seasonally flooded areas by reconnecting floodplains and historical drainage patterns.
Unidentified Wetland Community		High	Invasive species: *Lythrum salicaria, Phragmites australis* Excessive deer browse. Hydrology altered by previous dredge/fill activities.		
Phragmites Dominated Marsh		Low	Invasive species: *Phragmites australis* Hydrology altered by previous dredge/fill activities.		
Upland Forests	Early successional forest (<40 years)				
Acer negundo Forest		High	Invasive species: *Ailanthus altissema, Allaria petiolata, Cephalanthus orbiculatus, Humulus japonica, Lonicera japonica, Phragmites australis* Excessive deer browse. Hydrology altered by previous dredge/fill activities.		
Acer-Ulmus-Populus Forest		High	Invasive species: *Ailanthus altissema, Allaria petiolata, Humulus japonica, Lonicera japonica* Excessive deer browse. Hydrology altered by previous dredge/fill activities.		
Grasslands/Meadows	Meadows maintained for utility and road right-of-ways.				
Unidentified Meadow Community		High	Invasive species: *Ailanthus altissema, Cephalanthus orbiculatus, Humulus japonica, Lonicera japonica, Phragmites australis, Polyganum perfoliatum* Excessive deer browse. Right-of-way requirements prevent natural succession as part of management.		
Open Water	Potentially support state/federal species of concern.				
Hoys Pond and adjacent open water areas.		Low	Invasive species: *Phragmites australis*		

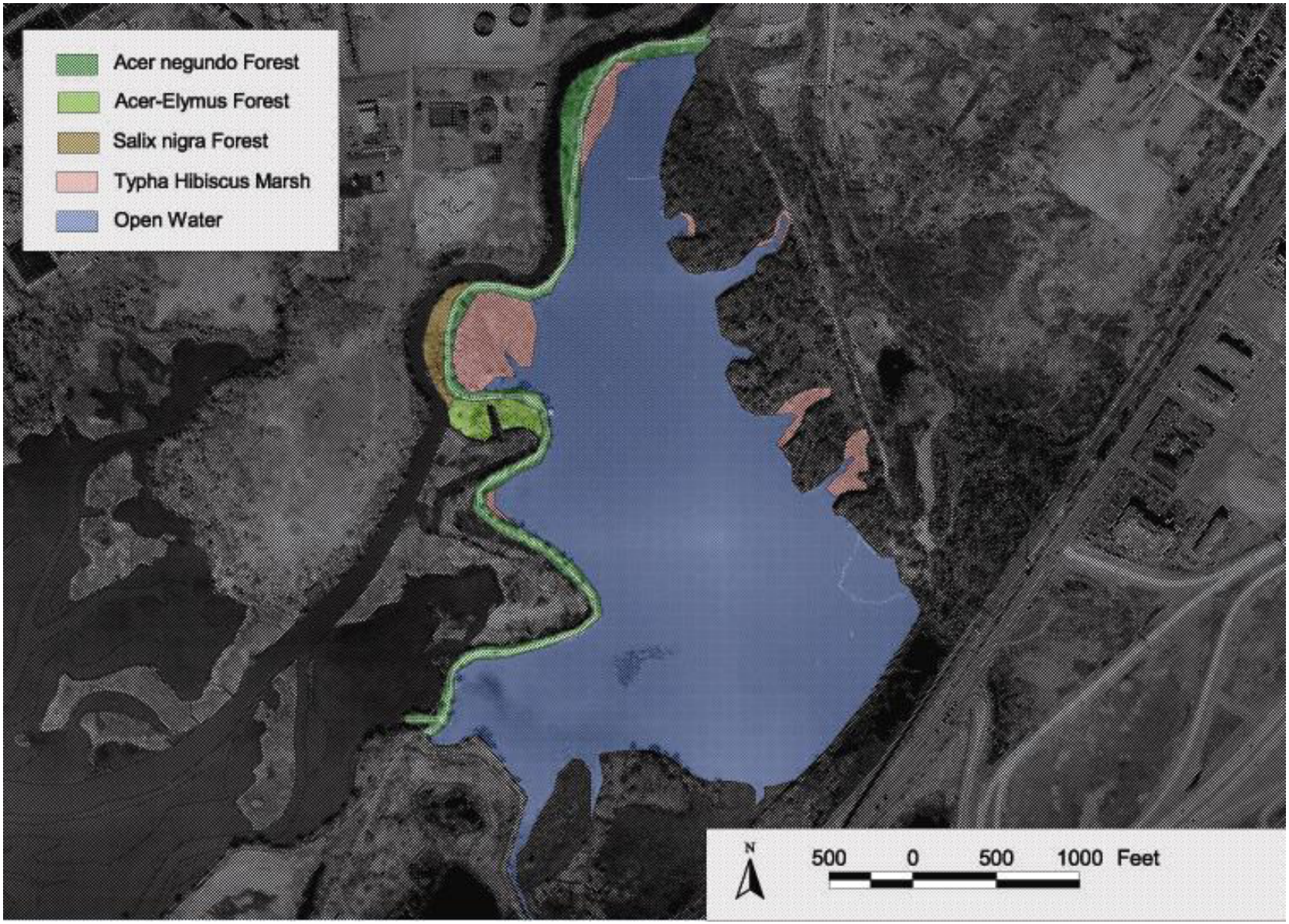
Management Unit: I-95 Outliers



Management Unit: I-95 Outliers

Ecological Components	Special Features	Management Priority Ranking	Restoration Obstacles	Short Term Actions	Long Term Actions
Upland Forests	Early successional forest (<40 years). Only location on Refuge with significant populations of high-tide bush (*Baccharis halmifolia)*.			• Establish vegetation monitoring plots and record baseline data for performance standards documentation. • Coordinate invasive species control and management of right-of-way with PennDOT and management contractors. • Control invasive species introductions focusing on priority species as identified on Table 2 Prioritized List of Invasive Species in priority areas (identified above).	• Collect data annually at vegetation monitoring plots and record baseline data for performance standards documentation. • Conduct biannual (May and August) search and control efforts to prevent new colonization of invasive species. • Continue invasive species control. • Monitor sub units for new invasive arrivals, including plants, insects, and other pathogens. • Native species re-introduction as needed to reach community diversity, structure, and function targets.
Acer negundo Forest		High	Invasive species: *Allaria petiolata, Cephalanthus orbiculatus, Lonicera japonica, Lonicera maackii, Phragmites australis, Polyganum perfoliatum, Rosa multiflora.* Hydrology altered by previous dredge/fill activities.		
Unidentified Forest Community		Medium	Invasive species: *Allaria petiolata, Cephalanthus orbiculatus, Lonicera japonica, Lonicera maackii, Phragmites australis, Polyganum perfoliatum, Rosa multiflora.* Hydrology altered by previous dredge/fill activities.		
Non-Tidal Wetlands	Pipeline right-of-way along length of sub-unit.				
Typha-*Hibiscus* marsh		Low	Invasive species: *Lythrum salicaria, Phragmites australis.* Hydrology altered by I-95 and stormwater runoff.		
Open Water					
Pocket wetlands and open water ponds		Low	Hydrology altered by stormwater runoff from I-95 and surrounding lands.		

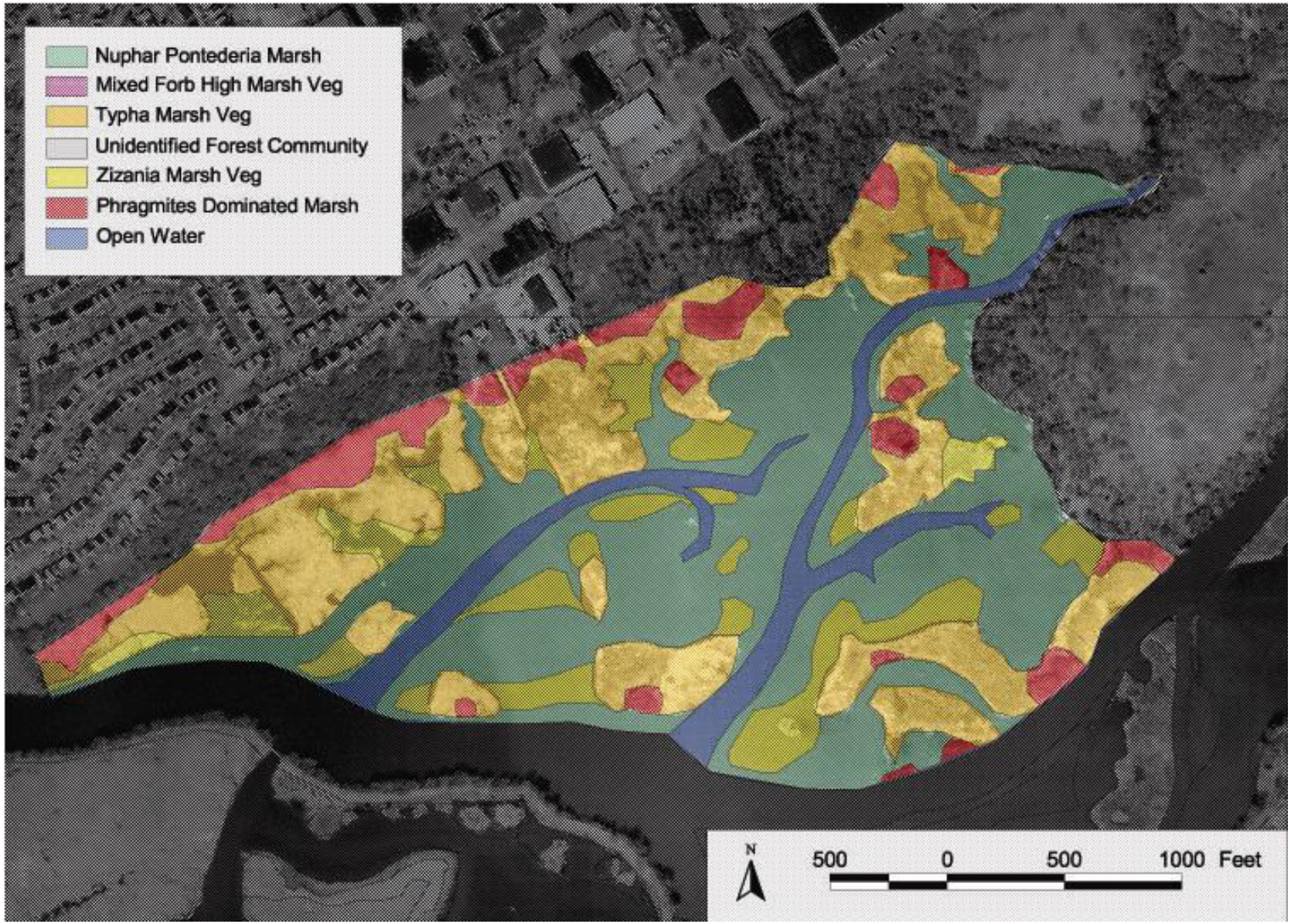
Management Unit: Impoundment and Dike



Management Unit: Impoundment and Dike

Ecological Components	Special Features	Management Priority Ranking	Restoration Obstacles	Short Term Actions	Long Term Actions
Freshwater Non-Tidal Wetlands	Hibiscus dominated marsh located along edges of Impoundment.			• Establish vegetation monitoring plots and record baseline data for performance standards documentation. • Control invasive species introductions focusing on the priority species as identified on Table 2 Prioritized List of Invasive Species in priority areas (identified above). • Focus native plant reintroductions in areas with poor stability, inadequate species diversity or composition, canopy gaps or other edge areas. • Continue seasonal manipulation of Impoundment water levels for migratory bird habitat enhancement. • Explore/Implement fish passage opportunities connecting Darby Creek and the Impoundment.	• Collect data annually at vegetation monitoring plots and record baseline data for performance standards documentation. • Conduct biannual (May and August) search and control effort to prevent new colonization of invasive species. • Continue invasive species control. • Monitor sub units for new invasive arrivals, including plants, insects, and other pathogens. • Reintroduce native species as needed to reach community diversity, structure, and function targets. • Reduce excessive deer browse. • Explore feasibility of restoring tidal influence to portions of the Impoundment.
Typha-Hibiscus Marsh		Low	Invasive species: *Lythrum salicaria, Polyganum perfoliatum.* Hydrologic alteration impedes establishment of Typha spp. normally associated with this community.		
Forests	Acer negundo Forest is located along Impoundment dike. Other forests are located on Darby Creek floodplain areas.				
Acer negundo Forest		High	Invasive species: *Acer platanoides, Allaria petiolata, Artemesia vulgaris, Cephalanthus orbiculatus, Lonicera japonica, Phragmites australis, Polyganum cuspidatum, Rosa multiflora.* Excessive deer browse.		
Acer saccharinum - Acer negundo / (Elymus virginicus) Forest		Low	Invasive species: *Allaria petiolata, Humulus japonica, Phragmites australis, Polyganum cuspidatum, Polyganum perfoliatum, Rosa multiflora.* Excessive deer browse.		
Salix nigra Forest		High	Invasive species: *Allaria petiolata, Cephalanthus orbiculatus, Humulus japonica, Lonicera maackii, Phragmites australis, Polyganum cuspidatum, Polyganum perfoliatum.* Excessive deer browse.		
Open Water	Impoundment is managed as open water/mudflat habitat for waterfowl and shorebird migrations.				
Impoundment		Low	Management as open water and/or mudflat habitat provides habitat enhancement for waterfowl and shorebirds, but does not allow for natural ecological processes.		

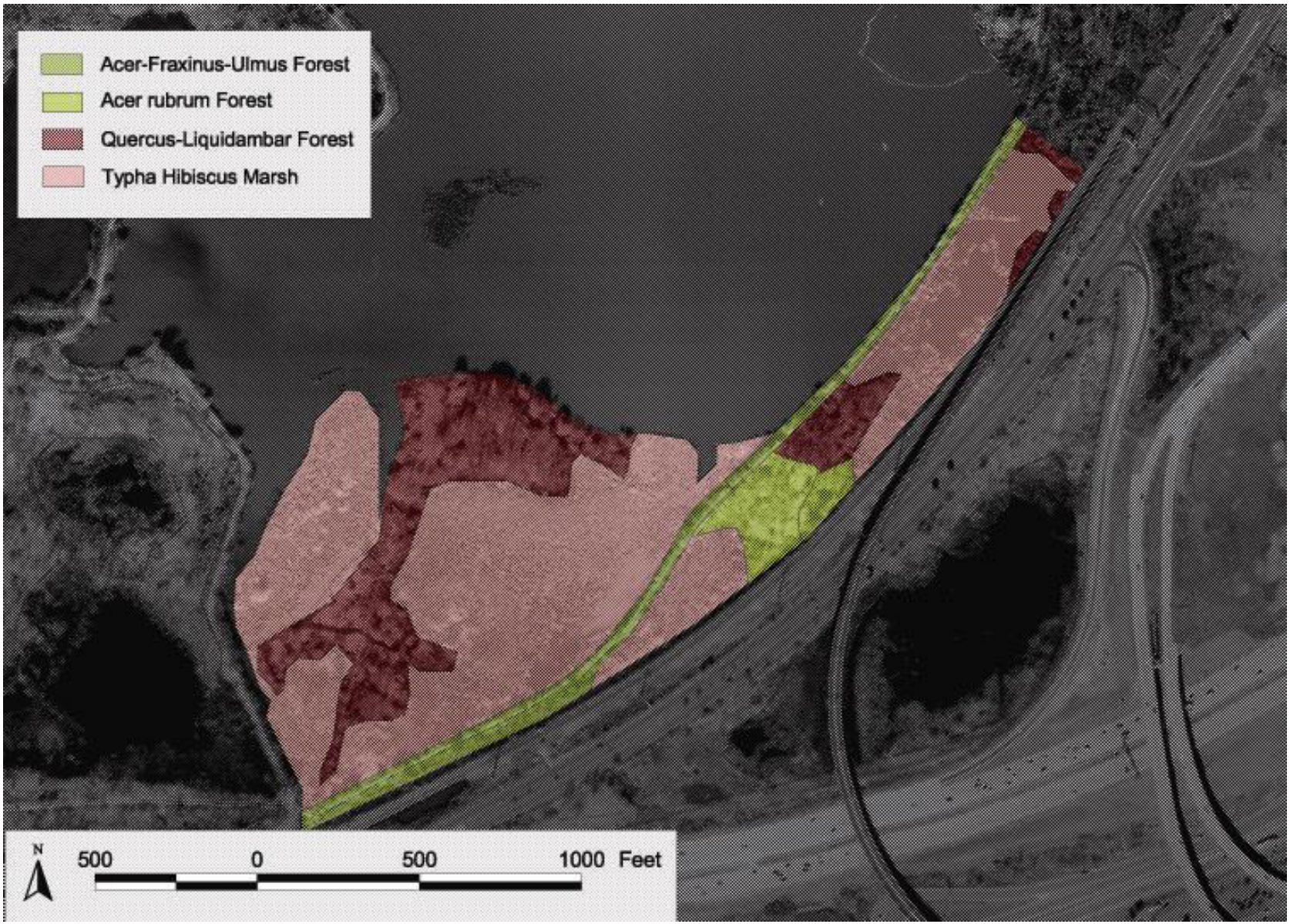
Management Unit: North Tidal Marsh



Management Unit: North Tidal Marsh

Ecological Components	Special Features	Management Priority Ranking	Restoration Obstacles	Short Term Actions	Long Term Actions
Freshwater Tidal Marsh	Ecological communities are highly dependent on marsh elevation.			• Preserve currently stable and functioning systems, especially those most vulnerable to degradation. • Establish vegetation monitoring plots and record baseline data for performance standards documentation. • Establish sediment accretion monitoring plots. • Control invasive species introductions focusing on *Phragmites australis* in priority areas (identified above). • Conduct biannual (May and August) search and control effort to prevent new colonization of invasive species.	• Collect data annually at vegetation monitoring plots and record baseline data for performance standards documentation. • Collect sediment accretion data annually to assess marsh response to changing sea level elevations. • Continue invasive species control. • Monitor sub units for new invasive arrivals, including plants, insects, and other pathogens. • Create partnerships with adjacent landowners to control invasive species and establish wetland buffers in areas and right-of-ways adjoining the marsh through maintenance agreements or incentives. • Continue involvement in Folcroft Landfill RI/FS process and develop marsh protection and monitoring objectives for the landfill closure.
Nuphar lutea Tidal Marsh		Low	Tolerance of tidal inundation makes this community resistant to known aquatic invasive species.		
Peltandra virginica - Pontederia cordata Tidal Herbaceous Vegetation		Low	Tolerance of tidal inundation makes this community resistant to known aquatic invasive species.		
Freshwater Tidal Mixed Forbs High Marsh		High	Potential for invasive species colonization by *Phragmites australis*.		
Typha (angustifolia, latifolia) - (Schoenoplectus spp.) Eastern Herbaceous Vegetation		High	Potential for invasive species colonization by *Phragmites australis*.		
Atlantic Coast Wild Rice Tidal Marsh		Medium	Potential for invasive species colonization by *Phragmites australis*.		
Phragmites Dominated Marsh		Medium	Invasive species: *Phragmites australis* Phragmites dominated areas should be restored to some other high marsh elevation community such as Mixed High Forbs Marsh or Wild Rice Marsh.		
Open Water	Areas along northern edge of marsh display signs of mosquito ditch dredging from the 1930's.				
Hermesprota and Little Thoroughfare Creeks		High	Pollution from watershed urbanization and Folcroft Landfill has severely impacted water quality in this system.		
Freshwater Intertidal Mudflat		High	Tolerance of tidal inundation makes this community resistant to known aquatic invasive species.		

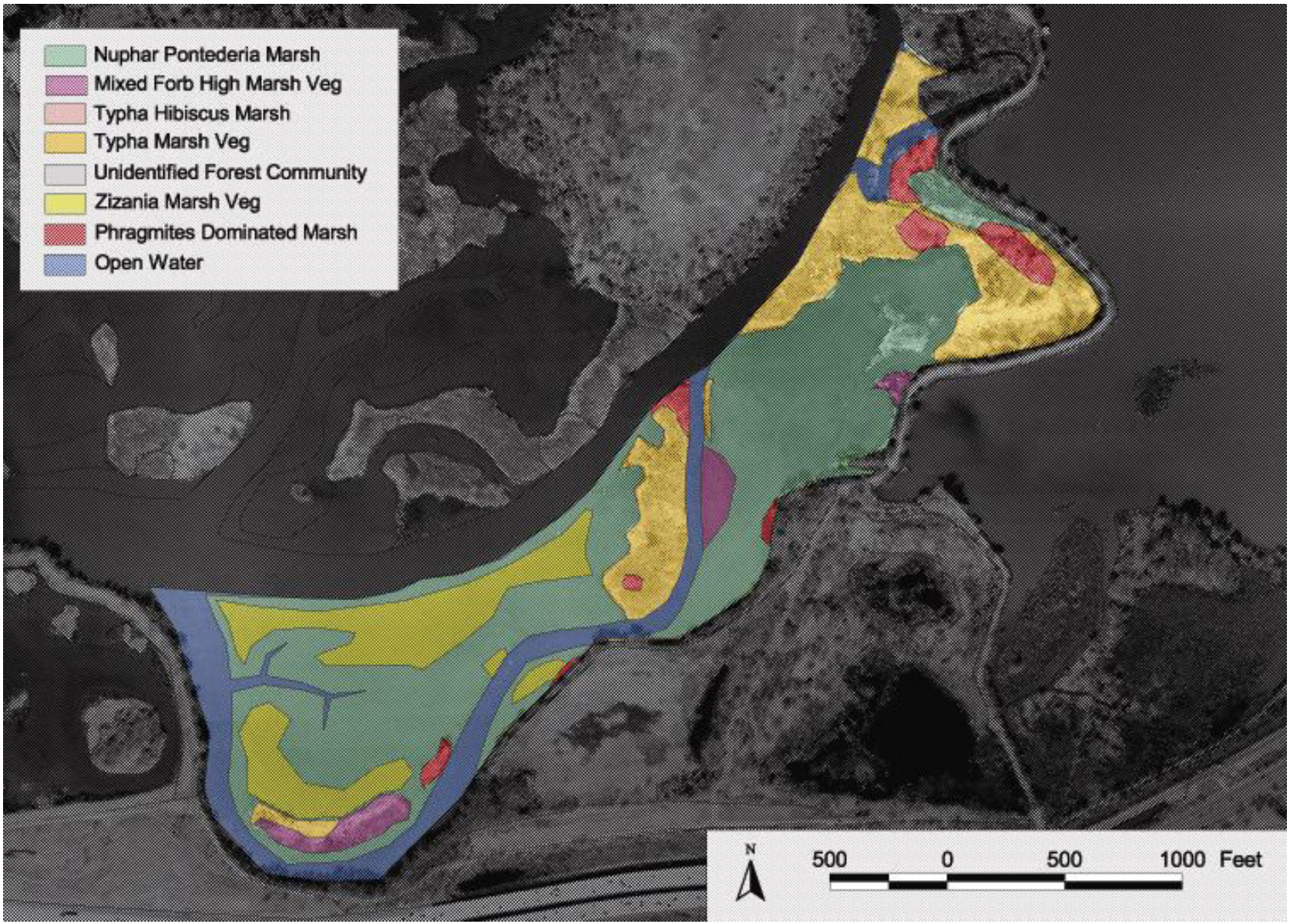
Management Unit: South Impoundment Forest



Management Unit: South Impoundment Forest

Ecological Components	Special Features	Management Priority Ranking	Restoration Obstacles	Short Term Actions	Long Term Actions
Freshwater Non-Tidal Wetlands	Hibiscus dominated marsh comprises a majority of this management unit. Acer-Fraxinus-Ulmus Forest is located along southern edge of the Impoundment on what was formerly the Philadelphia and Chester Railway.			• Establish vegetation monitoring plots and record baseline data for performance standards documentation. • Control invasive species introductions focusing on the priority species as identified on Table 2 Prioritized List of Invasive Species in priority areas (identified above). • Create partnerships with adjacent landowners to control invasive species and establish maintenance agreements on lands and right-of-ways adjoining the management unit. • Focus native plant reintroductions in areas with poor stability, inadequate species diversity or composition, canopy gaps or other edge areas. • Research effects of environmental noise levels on species utilization within management unit.	• Collect data annually at vegetation monitoring plots and record baseline data for performance standards documentation. • Conduct biannual (May and August) search and control effort to prevent new colonization of invasive species. • Continue invasive species control. • Monitor sub units for new invasive arrivals, including plants, insects, and other pathogens. • Reintroduce native species as needed to reach community diversity, structure, and function targets. • Reduce excessive deer browse.
Typha-Hibiscus Marsh		Low	Invasive species: *Lythrum salicaria, Phragmites australis, Polyganum perfoliatum.* Hydrologic alteration impedes establishment of Typha spp. normally associated with this community.		
Forests	Portions of this management unit are difficult to access due to seasonal high water tables or areas of open water.				
Acer (rubrum, saccharinum) - Fraxinus spp. - Ulmus americana Forest		High	Invasive species: *Ligustrum arvense, Lonicera japonica, Lythrum salicaria, Phragmites australis, Polyganum perfoliatum, Rosa multiflora.*		
Acer rubrum Forest		Low	Invasive species: No invasive species were recorded at the time of the field survey. Excessive deer browse.		
Quercus palustris - Quercus bicolor - (Liquidambar styraciflua) Mixed Hardwood Forest		Medium/High	Invasive species: *Allaria petiolata, Cephalanthus orbiculatus, Lonicera japonica, Lythrum salicaria, Phragmites australis, Polyganum perfoliatum, Rosa multiflora.* Excessive deer browse.		

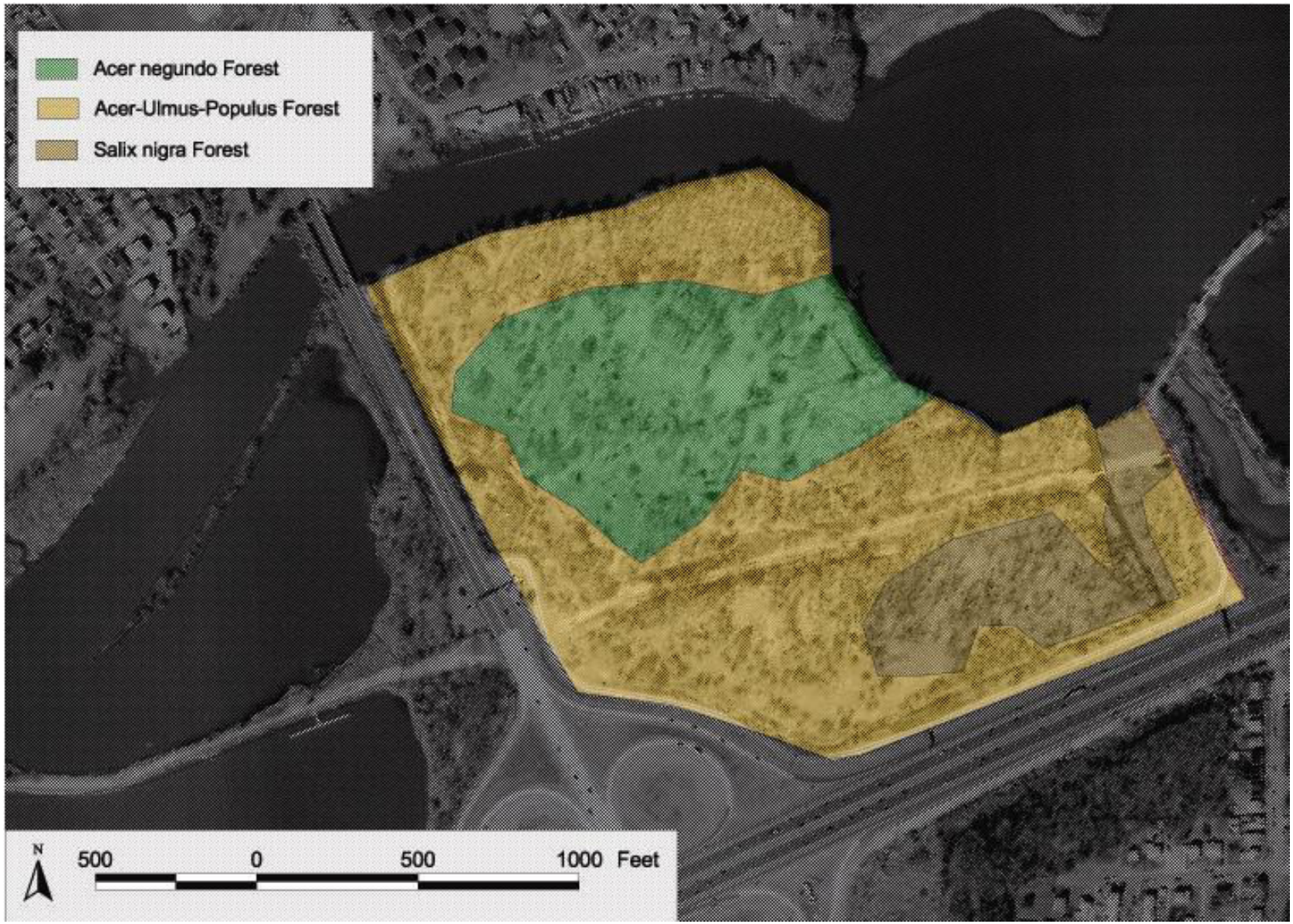
Management Unit: South Tidal Marsh



Management Unit: South Tidal Marsh

Ecological Components	Special Features	Management Priority Ranking	Restoration Obstacles	Short Term Actions	Long Term Actions
Freshwater Tidal Marsh	Ecological communities are highly dependent on marsh elevation.			• Preserve currently stable and functioning systems, especially those most vulnerable to degradation. • Establish vegetation monitoring plots and record baseline data for performance standards documentation. • Establish sediment accretion monitoring plots. • Control invasive species introductions focusing on *Phragmites australis* in priority areas (identified above). • Conduct biannual (May and August) search and control effort to prevent new colonization of invasive species.	• Collect data annually at vegetation monitoring plots and record baseline data for performance standards documentation. • Collect sediment accretion data annually to assess marsh response to changing sea level elevations. • Continue invasive species control. • Monitor sub units for new invasive arrivals, including plants, insects, and other pathogens. • Create partnerships with adjacent landowners to control invasive species and establish wetland buffers in areas and right-of-ways adjoining the marsh through maintenance agreements or incentives. • Continue involvement in Folcroft Landfill RI/FS process and develop marsh protection and monitoring objectives for the landfill closure.
Nuphar lutea Tidal Marsh		Low	Tolerance of tidal inundation makes this community resistant to known aquatic invasive species.		
Peltandra virginica - Pontederia cordata Tidal Herbaceous Vegetation		Low	Tolerance of tidal inundation makes this community resistant to known aquatic invasive species.		
Freshwater Tidal Mixed Forbs High Marsh		High	Potential for invasive species colonization by *Phragmites australis*.		
Typha (angustifolia, latifolia) - (Schoenoplectus spp.) Eastern Herbaceous Vegetation		High	Potential for invasive species colonization by *Phragmites australis*.		
Atlantic Coast Wild Rice Tidal Marsh		Medium	Potential for invasive species colonization by *Phragmites australis*.		
Phragmites Dominated Marsh		Medium	Invasive species: *Phragmites australis* Phragmites dominated areas should be restored to some other high marsh elevation community such as Mixed High Forbs Marsh or Wild Rice Marsh.		
Open Water					
Darby Creek		High	Pollution from watershed urbanization and Folcroft Landfill has severely impacted water quality in this system.		
Freshwater Intertidal Mudflat		High	Tolerance of tidal inundation makes this community resistant to known aquatic invasive species.		

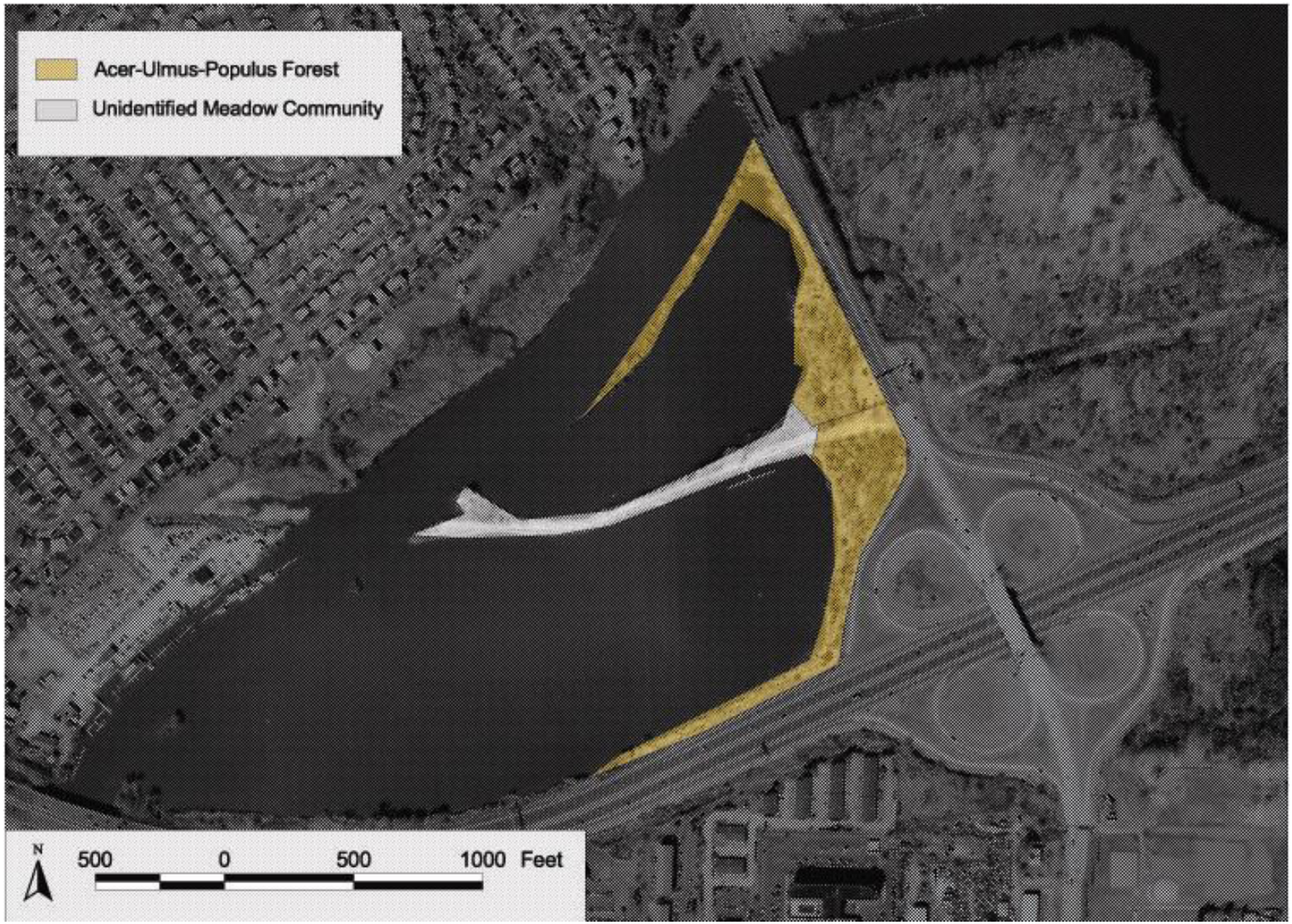
Management Unit: State Road 420 East



Management Unit: State Road 420 East

Ecological Components	Special Features	Management Priority Ranking	Restoration Obstacles	Short Term Actions	Long Term Actions
Upland Forests	Early successional forest (<40 years)			Establish vegetation monitoring plots and record baseline data for performance standards documentation. Coordinate invasive species control and management of right-of-way with utility owners and management contractors. Create and enforce BMP's along right-of-way corridors. Control invasive species introductions focusing on priority species as identified on Table 2 Prioritized List of Invasive Species in priority areas (identified above). Focus effort on restoration of management unit to freshwater tidal marsh (or native grasslands along right-of-ways). Restore floodplain hydrology to impaired seasonally flooded areas by reconnecting floodplains and historical drainage patterns while maintaining infrastructure right-of-way protections.	Collect data annually at vegetation monitoring plots and record baseline data for performance standards documentation. Conduct biannual (May and August) search and control efforts to prevent new colonization of invasive species. Continue invasive species control. Monitor sub units for new invasive arrivals, including plants, insects, and other pathogens. Native species re-introduction as needed to reach community diversity, structure, and function targets. Reduce excessive deer browse.
Acer negundo Forest		Low	Invasive species: *Allaria petiolata, Humulus japonica, Lonicera japonica, Microstegium vimeneum, Phragmites australis, Polyganum perfoliatum.* Excessive deer browse. Hydrology altered by previous fill activities. Pipeline right-of –way management maintains early successional conditions and does not currently address invasive species within management area.		
Acer-Ulmus-Populus Forest		Low	Invasive species: *Ailanthus altissema, Allaria petiolata, Humulus japonica, Lonicera japonica, Microstegium vimeneum, Phragmites australis, Polyganum cuspidatum, Polyganum perfoliatum.* Excessive deer browse. Hydrology altered by previous dredge/fill activities.		
Salix nigra Forest		Low	Invasive species: *Phragmites australis* Excessive deer browse. Hydrology altered by previous dredge/fill activities.		

Management Unit: State Road 420 West



Management Unit: State Road 420 West

Ecological Components	Special Features	Management Priority Ranking	Restoration Obstacles	Short Term Actions	Long Term Actions
Upland Forests	Early successional forest (<40 years). Forest shows least signs of deer browse of anywhere on the Refuge.			• Establish vegetation monitoring plots and record baseline data for performance standards documentation. • Coordinate invasive species control and management of right-of-way with utility owners and management contractors. Create and enforce BMP's along right-of-way corridors. • Control invasive species introductions focusing on priority species as identified on Table 2 Prioritized List of Invasive Species in priority areas (identified above). • Monitor erosion effects of wake created by watercraft along Darby Creek	• Collect data annually at vegetation monitoring plots and record baseline data for performance standards documentation. • Conduct biannual (May and August) search and control efforts to prevent new colonization of invasive species. • Continue invasive species control. • Monitor sub units for new invasive arrivals, including plants, insects, and other pathogens. • Native species re-introduction as needed to reach community diversity, structure, and function targets.
Acer-Ulmus-Populus Forest		Medium	Invasive species: *Allaria petiolata, Cephalanthus orbiculatus, Lonicera japonica, Phragmites australis, Polyganum perfoliatum.* Hydrology altered by previous dredge/fill activities.		
Grasslands/Meadows	Pipeline right-of-way along length of sub-unit.				
Unidentified Meadow Community		Low	Invasive species: *Artemesia vulgare, Lonicera japonica, Lythrum salicaria, Phragmites australis, Polyganum perfoliatum, Rosa multiflora.* Hydrology altered by previous fill activities. Pipeline right-of –way management maintains early successional conditions and does not currently address invasive species within management area.		
Open Water	Potentially support state/federal species of concern				
Lower Darby Creek and adjacent open water areas.		High	Invasive species: *Phragmites australis* Hydrology altered by previous dredge activities.		

APPENDIX B

IDENTIFIED ECOLOGICAL SYSTEMS AND THEIR COMMUNITIES

The following identification and summary information is provided primarily by the *Guide to Natural Communties of the Delaware Estuary* (Westervelt 2006) and the NatureServe Explorer database*. The Delaware Riverkeeper Network developed or edited management concerns for each community based on conditions observed at the Refuge.

Ecological System and Community Types

Freshwater Tidal Marsh

System Name**:** Northern Atlantic Coastal Plain Fresh & Oligohaline Tidal Marsh (CES203.516)
Includes all non-forested wetland areas that are tidally influenced. Found in *North Tidal Marsh*, *South Tidal Marsh*, and *Henderson Dike and Marsh* management units, it is comprised of the following ecological communities:

- Atlantic Coast Wild Rice Tidal Marsh
- Freshwater Tidal Mixed Forbs High Marsh
- Nuphar lutea Tidal Marsh
- Peltandra virginica - Pontederia cordata Tidal Herbaceous Vegetation
- Phragmites Dominated Marsh
- Typha (angustifolia, latifolia) - (Schoenoplectus spp.) Eastern Herbaceous Vegetation

Freshwater Non-tidal Marsh

System Name: Northern Atlantic Coastal Plain Pondshore (CES203.518)
Includes all non-forested wetland areas that are non-tidal. Found in *Impoundment*, *South Impoundment Forest*, and *Hoys Pond Area* management units, it is comprised of the following ecological communities:

- Phragmites Dominated Marsh (*see description under Freshwater Tidal Marsh*)
- Typha angustifolia - Hibiscus moscheutos Herbaceous Vegetation
- Unidentified Wetland Community

Open Water

System Name: Northern Atlantic Coastal Plain Sub-tidal Aquatic Bed (CES203.521)

While open water itself does not constitute an ecological community, the bed characteristics of those areas do. This includes all stream and marsh channel beds that are tidal. Found in *Darby Creek*, *Henderson Dike and Marsh, North Tidal Marsh,* and *South Tidal Marsh* management units, it is comprised of the following ecological communities:

- Freshwater Intertidal Mudflat

Riparian and Upland Forests

System Name: Central Appalachian Floodplain (CES202.608)

Includes forested riparian and upland areas that are non-tidal. Found in *Cusano Area, East Impoundment Forest, South Impoundment Forest, Hoys Pond Area, Henderson Dike and Marsh, I-95 Outliers, Impoundment*, *State Road 420 East, and State Road 420 West* management units, it is comprised of the following ecological communities:

- Acer negundo Forest
- Acer rubrum Forest
- Acer saccharinum - Acer negundo/(Elymus virginicus) Forest
- Acer (rubrum, saccharinum) - Fraxinus spp. - Ulmus americana Forest
- Acer saccharinum - Ulmus americana - (Populus deltoides) Forest
- Prunus serotina - Acer rubrum - Amelanchier canadensis - Quercus spp. Forest Alliance
- Quercus palustris - Quercus bicolor - (Liquidambar styraciflua) Mixed Hardwood Forest
- Salix nigra Temporarily Flooded Shrubland
- Unidentified Forest Community

Riparian and Upland Grasslands

System Name: Unspecified

Includes riparian and upland grasslands that are non-tidal. These typically include areas either regularly mowed to maintain utility right-of-ways or areas recently restored with a mix of warm-season grasses. Found in *Cusano Area, East Impoundment Forest, Hoys Pond Area, Henderson Dike and Marsh, I-95 Outliers, and State Road 420 West* management units, it is comprised of the following ecological communities:

- Little Bluestem - Yellow Indiangrass Herbaceous Alliance
- Unidentified Meadow Community

Wild rice/Zizania aquatica Tidal Herbaceous Vegetation

Common Name: Atlantic Coast Wild Rice Tidal Marsh

Unique Identifier: CEGL004202

Classification Approach: International Vegetation Classification (IVC)

Range: This association occurs along the Atlantic Coastal Plain from Maine and Massachusetts south to South Carolina, possibly extending into Georgia. This association occurs in New Jersey and possibly Delaware in the Delaware Estuary.

Environmental Description: This association occurs in the lower reaches of freshwater tidal marshes, in fresh to slightly brackish areas that are low within the marsh and are infrequently exposed at lowest tides. It occurs on alluvial soils that are commonly silts or silty clays, although occasionally have a greater sand component. *Zizania* (wild rice) flats are best developed in quiet waters conducive to sedimentation (Barrett 1989).

Vegetation Description: This freshwater tidal marsh community can be highly variable in species composition but is characterized by *Zizania aquatica* (Indian wild rice), which is dominant and monotypic in some examples, or codominant with such species as *Pontederia cordata* (pickerelweed), *Peltandra virginica* (green arrow-arum), *Polygonum arifolium* (halberd-leaf tearthumb), *Polygonum punctatum* (dotted smartweed), and/or *Bidens cernua* (nodding beggarticks), among others. Common associates are generally a mixture of freshwater and brackish species and can include *Sagittaria latifolia* (broadleaf arrowhead), *Ludwigia palustris* (marsh seedbox), *Impatiens capensis* (orange jewelweed), *Leersia oryzoides* (rice cutgrass), *Amaranthus cannabinus* (water-hemp), *Hibiscus moscheutos* (eastern rosemallow), *Sium suave* (hemlock water-parsnip), *Acorus americanus* (several-vein sweetflag), and *Schoenoplectus fluviatilis* (river bulrush). *Nuphar lutea ssp. advena* (broadleaf pond-lily) is a common associate in the southern portion of the range. This plant association shows extreme seasonal variability, with *Zizania aquatica* (Indian wild rice) becoming a conspicuous component only in mid to late summer and generally senescing by mid to late autumn. This vegetation provides an important food source for migratory birds.

Noteworthy Associated Plant and/or Animal Species: *Aeschynomene virginica* (Virginia joint-vetch)

Characteristic Species: *Zizania aquatica* (Indian wild rice)

Dynamics/Successional Trajectory: Freshwater tidal marshes are naturally dynamic systems that are best developed where there is a major input of freshwater, a daily tidal range of at least 0.5 m, and a geomorphology that tends to constrict and magnify tidal influence in the upper reaches of the estuary (Odum et al. 1984). They are subject to diurnal flooding by tides and seasonal and episodic flooding from river discharge. Plant composition of freshwater tidal marshes generally occurs as a mosaic of patches dominated by a few or a single species. Species composition is determined by species life history characteristics, especially lifeform, phenology and mode of regeneration in response to microhabitat conditions, and the frequency and duration of flooding. Plant composition has seasonal variation. Landward, this community can grade into other freshwater tidal marsh associations, especially *Peltandra virginica - Pontederia cordata* Tidal Herbaceous Vegetation (CEGL004706).

Reference Sites: Manumuskin River (TNC Preserve), NJ; Rancocas Creek at Mill Creek (Willingboro Township) Park, Burlington County, NJ

Global and State Conservation Ranks and Reasons: G4? (13-Aug-1997). DE: S3, NJ: S2S3.

References: Barrett 1989, Barrett 1994, Bowman 2000, Breden 1989, Breden et al. 2001, Coulling 2002, Eastern Ecology Working Group n.d., Edinger et al. 2002, Enser 1999, Ferren and Good 1977, Fleming et al. 2001, Gawler 2001, Gawler 2002, Glitzenstein and Streng 2004, Good and Good 1975b, Harrison 2001, Harrison 2004, McCormick and Ashbaugh 1972, McCormick et al. 1970, McCoy and Fleming 2000, Metzler and Barrett 2001, Metzler and Rosza 1982, Odum et al. 1984, Rawinski 1984, Reschke 1990, Schafale 2000, Schafale 2003b, Schafale and Weakley 1990, Swain and Kearsley 2001, VDNH 2003, Wharton 1978.

Management Concerns: This community is most successful within a narrow tidal elevation range (less than six inches). Future tidal marsh restoration projects should attempt to replicate reference locations of this community located in the North and South Tidal Marsh management units. Due to its elevation requirements, invasion by *Phragmites australis* is of moderate concern.

Impatiens capensis - Peltandra virginica - Sagittaria latifolia - (Typha angustifolia) Tidal Herbaceous Vegetation

Common Name: Freshwater Tidal Mixed Forbs High Marsh

Unique Identifier: CEGL006325

Classification Approach: International Vegetation Classification (IVC)

Range: This association occurs in freshwater tidal marshes along the Atlantic coast from Maine to Virginia. It occurs in the New Jersey portion of the Delaware Estuary.

Environmental Description: This association occurs in reliably flooded swales or backmarshes within the upper reaches of freshwater tidal marshes and within naturally ice-scoured levees and creekbanks. Salinity is fresh to slightly brackish. These low-lying depressions are flooded for a longer duration than the surrounding habitat as they trap floodwaters as tides recede. Soils are highly variable, ranging from silts, silty mucks, peats, or sands.

Vegetation Description: Species composition and abundance in these small-patch wet depression are highly variable. They are best characterized by the presence and/or dominance of *Peltandra virginica* (green arrow-arum), *Impatiens capensis* (orange jewelweed), *Sagittaria latifolia* (broadleaf arrowhead), and/or *Typha angustifolia* (narrowleaf cattail). Associated species commonly include *Pontederia cordata* (pickerelweed), *Polygonum* (smartweed, knotweed) spp. (*Polygonum arifolium* (halberd-leaf tearthumb), *Polygonum sagittatum* (arrowleaf tearthumb), *Polygonum hydropiperoides* (swamp smartweed), *Polygonum punctatum* (dotted smartweed), *Bidens* (beggarticks) spp. (*Bidens laevis* (smooth beggarticks), *Bidens frondosa* (devil's pitchfork), *Schoenoplectus fluviatilis* (river bulrush), *Leersia oryzoides* (rice cutgrass), *Amaranthus cannabinus* (water-hemp), *Sium suave* (hemlock water-parsnip), *Apios americana* (groundnut), *Iris versicolor* (harlequin blueflag), *Echinochloa walteri* (long-awn cock's-spur grass), and others. The exotic *Murdannia keisak* (marsh dewflower) has been noted in this community in the southern portion of the range. Species of the surrounding oligohaline or mesohaline marshes or from palustrine setting can occur in these microhabitats, but are usually not dominant; these include *Zizania aquatica* (Indian wild rice), *Onoclea sensibilis* (sensitive fern), *Hibiscus moscheutos* (eastern rosemallow), *Cyperus strigosus* (straw-colored flatsedge), *Lindernia dubia* (yellowseed false pimpernel), *Equisetum fluviatile* (water horsetail), *Iris versicolor* (harlequin blueflag), *Boehmeria cylindrica* (small-spike false nettle), *Thelypteris palustris* (eastern marsh fern), or *Carex stricta* (tussock sedge).

Noteworthy Associated Plant and/or Animal Species: *Bidens bidentoides* (Delmarva beggarticks), *Justicia Americana* (American water-willow)
Characteristic Species: *Impatiens capensis* (orange jewelweed), *Peltandra virginica* (green arrow-arum), *Sagittaria latifolia* (broadleaf arrowhead), *Typha angustifolia* (narrowleaf cattail)
Dynamics/Successional Trajectory: Freshwater tidal marshes are naturally dynamic systems that are best developed where there is a major input of freshwater, a daily tidal range of at least 0.5 m, and a geomorphology that tends to constrict and magnify tidal influence in the upper reaches of the estuary (Odum et al. 1984). They are subject to diurnal flooding by tides and seasonal and episodic flooding from river discharge. Plant composition of freshwater tidal marshes generally occurs as a mosaic of patches dominated by a few or a single species. Species composition is determined by species life history characteristics, especially lifeform, phenology and mode of regeneration in response to microhabitat conditions, and the frequency and duration of flooding. Plant composition has seasonal variation. This association occurs in microhabitats within freshwater tidal marsh systems. As the low-lying depressions fill with sediment, the vegetation shifts to reflect the surrounding association. This association is also very similar to Water-hemp Tidal Marsh (oligohaline), *Amaranthus cannabinus* Tidal Herbaceous Vegetation (Water Hemp Tidal Marsh in this report), and may grade temporally with annual rainfall/tidal influence.
Reference Sites: Hamilton Marsh, Mercer County, NJ; Trenton Marsh, Mercer County, NJ; Pedricktown Marsh; Mill Creek (Willingboro Township) Park, Burlington County, NJ
Global and State Conservation Ranks and Reasons: GNR (1-Dec-1997). DE: S4, NJ: S3, PA?: SNA.
VegBank Link for Plot Data: http://vegbank.org/natureserve/element_global.2.689421
References: Barrett 1989, Barrett 1994, Bartgis 1986, Bowman 2000, Breden 1989, Breden et al. 2001, Clancy 1996, Coulling 2002, Eastern Ecology Working Group n.d., Edinger et al. 2002, Fleming 2001, Fleming et al. 2001, Gawler 2002, Harrison 2001, Harrison 2004, Metzler and Barrett 2001, Metzler and Barrett 2004, Rawinski 1984, Reschke 1990, Swain and Kearsley 2001, VDNH 2003
Management Concerns: This community is found at the upper boundaries of tidal elevations. Future tidal marsh restoration projects should attempt to replicate reference locations of this community located in the North and South Tidal Marsh management units. Due to its high marsh elevation, invasion by *Phragmites australis* is of major concern. Westervelt notes that the exotic *Murdannia keisak* (marsh dewflower) has been noted in this community in the southern portion of the range.

Nuphar lutea Tidal Herbaceous Vegetation

Common Name: Pond-lily Tidal Marsh
Unique Identifier: CEGL004472
Classification Approach: International Vegetation Classification (IVC)
Range: This association occurs along tidal rivers from New York to North Carolina. In the Delaware Estuary, this community occurs in New Jersey and Delaware.
Environmental Description: This association occurs at low elevations within freshwater tidal marshes, within tidal range but beyond the influence of salinity. It generally occurs below mean low water level where water depth is approximately 1-3 m or less. It receives a relatively long duration of flooding and is infrequently exposed at only the lowest tides. The association occurs on unconsolidated tidal mud flats and submerged point bars of large coastal river meanders adjacent to open water of river or tidal creek channels. Substrate is silty alluvial mud that is high in organic matter content.

Vegetation Description: Vegetation of this association is characterized by large clonal stands of dense leafy forbs dominated by *Nuphar lutea ssp. advena* (broadleaf pond-lily). Associated species tend to occur as scattered individuals and include *Peltandra virginica* (green arrow-arum), which can also be locally codominant, *Pontederia cordata* (pickerelweed), *Zizania aquatica* (Indian wild rice), *Sagittaria latifolia* (broadleaf arrowhead), *Bidens laevis* (smooth beggarticks), *Acorus calamus* (sweetflag), and/or *Schoenoplectus fluviatilis* (river bulrush). *Nuphar lutea ssp. advena* (broadleaf pond-lily) forms nearly monotypic stands early in the growing season. Associated species emerge later in the season and can eventually overtop *Nuphar* (yellow pond-lily) plants, which senesce and tend to become insect-infested in late summer. Submerged aquatic species can occur in this association, including *Potamogeton epihydrus* (ribbonleaf pondweed), *Ceratophyllum demersum* (coontail), and the invasive exotic *Hydrilla verticillata* (hydrilla). In shallower waters, additional mud flat species can occur.
Characteristic Species: *Nuphar lutea* ssp. *advena* (broadleaf pond-lily)
Dynamics/Successional Trajectory: Freshwater tidal marshes are naturally dynamic systems that are best developed where there is a major input of freshwater, a daily tidal range of at least 0.5 m, and a geomorphology that tends to constrict and magnify tidal influence in the upper reaches of the estuary (Odum et al. 1984). They are subject to diurnal flooding by tides and seasonal and episodic flooding from river discharge. Plant composition of freshwater tidal marshes generally occurs as a mosaic of patches dominated by a few or a single species. Species composition is determined by species life history characteristics, especially lifeform, phenology and mode of regeneration in response to microhabitat conditions, and the frequency and duration of flooding. Plant composition has seasonal variation. Landward, this community can grade into other freshwater tidal marsh associations, especially *Peltandra virginica - Pontederia cordata* Tidal Herbaceous Vegetation (CEGL004706). Seaward, this association grades into submerged aquatic vegetation.
Reference Sites: Hamilton Marsh, Mercer County, NJ
Global and State Conservation Ranks and Reasons: G4G5 (19-Jan-2006). DE: SNR, NJ: S2S3, PA: SNR. This vegetation ranges from Delaware Bay to North Carolina, with a discontinuous range north to Maine. It occurs in the freshwater tidal portions of large rivers and embayments and can occupy large patches.
VegBank Link for Plot Data: http://vegbank.org/natureserve/element_global.2.688122
References: Bowman 2000, Breden 1989, Breden et al. 2001, Brumback and Mehrhoff 1996, Coulling 2002, Eastern Ecology Working Group n.d., Edinger et al. 2002, Fleming 2001, Fleming et al. 2001, Gawler 2002, Good and Good 1975b, Harrison 2001, Harrison 2004, McCormick and Ashbaugh 1972, McCormick et al. 1970, McCoy and Fleming 2000, Odum et al. 1984, Peet et al. unpubl. data 2002, Rawinski 1984, Reschke 1990, Schafale 2000, Schafale and Weakley 1990, VDNH 2003
Management Concerns: Field observations and data reviewed during development of the restoration plan show this community to be resistant to degradation as a result of its low tidal elevations. Westervelt also notes that the invasive *Hydrilla verticillata* (hydrilla) often occurs in this community and that vegetation is vulnerable to pollution from coastal run-off as well as oil spills off the coast.

Peltandra virginica - Pontederia cordata Tidal Herbaceous Vegetation

Common Name: Pickerelweed Tidal Marsh

Unique Identifier: CEGL004706

Classification Approach: International Vegetation Classification (IVC)

Range: This community occurs from Maine to Virginia, excluding Rhode Island and New Hampshire. It occurs in the New Jersey and Delaware portions of the Delaware Estuary.

Environmental Description: This community occurs low within freshwater tidal marshes on muck substrates of variable depth. There is a long duration of tidal flooding, and the community is exposed only for a short period of time each day when the tide is out.

Vegetation Description: This community is dominated by leafy forbs. *Peltandra virginica* (green arrow-arum) and *Pontederia cordata* (pickerelweed) are codominant, and associated species can include *Zizania aquatica* (Indian wild rice), *Sagittaria latifolia* (broadleaf arrowhead), *Acorus americanus* (several-vein sweetflag), *Polygonum arifolium* (halberd-leaf tearthumb), *Polygonum hydropiperoides* (swamp smartweed), *Polygonum sagittatum* (arrowleaf tearthumb), and *Bidens* (beggarticks) spp. Species occurring less frequently can include *Typha* (cattail) spp. and *Impatiens capensis* (orange jewelweed).

Characteristic Species: *Peltandra virginica* (green arrow-arum), *Pontederia cordata* (pickerelweed)

Dynamics/Successional Trajectory: Freshwater tidal marshes are naturally dynamic systems that are best developed where there is a major input of freshwater, a daily tidal range of at least 0.5 m, and a geomorphology that tends to constrict and magnify tidal influence in the upper reaches of the estuary (Odum et al. 1984). They are subject to diurnal flooding by tides and seasonal and episodic flooding from river discharge. Plant composition of freshwater tidal marshes generally occurs as a mosaic of patches dominated by a few or a single species. Species composition is determined by species life history characteristics, especially lifeform, phenology and mode of regeneration in response to microhabitat conditions, and the frequency and duration of flooding. Plant composition has seasonal variation. This community can grade into other freshwater tidal marsh associations, especially *Nuphar lutea ssp. advena* Tidal Herbaceous Vegetation (Pond Lily Tidal Marsh in this report) and *Zizania aquatica* Tidal Herbaceous Vegetation (Atlantic Coast Wild Rice Marsh in this report).

Reference Sites: Supawna Meadows NWR, NJ; Clinton WMA, NJ; Pedricktown Marsh Complex, NJ; Mannington Meadows, NJ; Manumuskin River (TNC Preserve), NJ

Global and State Conservation Ranks and Reasons: G3G4 (4-Nov-1998). DE: SNR, NJ: SNR. This community is restricted in range (Atlantic Coast from Maine to Virginia, not including New Hampshire and Rhode Island) and available habitat (freshwater tidal rivers with broad shoreline expanses subjected to moderate to high tidal fluctuation), with a liberal estimate of <200 EOs and <35,000 acres rangewide.

VegBank Link for Plot Data: http://vegbank.org/natureserve/element_global.2.688713

References: Bowman 2000, Breden et al. 2001, Coulling 2002, Eastern Ecology Working Group n.d., Edinger et al. 2002, Fleming 2001, Fleming et al. 2001, Harrison 2001, Harrison 2004, McCoy and Fleming 2000, Metzler and Barrett 2004, Odum et al. 1984, Peet et al. unpubl. data 2002

Management Concerns: Field observations and data reviewed during development of the restoration plan show this community to be resistant to degradation as a result of its moderate tidal elevations. However, upper limits of this community have potential for invasion by *Phragmites australis*. Westervelt notes that throughout its range this community has been impacted by damming of tidal rivers and by pollution in urban areas.

Phragmites australis Dominated Marsh

Translated Name: Common Reed Tidal Herbaceous Alliance
Unique Identifier: A.1477
Classification Approach: International Vegetation Classification (IVC)
Summary: At the Refuge, this alliance includes specifically the invasive freshwater tidal marsh communities dominated by (often essentially monospecific) *Phragmites australis*. However, this alliance officially is known to include native communities of this species as well. Although *Phragmites australis* rhizomes have been noted in salt marsh sediments exceeding 3000 years in age and it is thus a native component of salt marshes in some areas of North America, the growth habit of the species in its native condition was likely to have been significantly different than the dense monotypic, invasive stands documented in this alliance. Evidence suggests that a new, more invasive genotype of *Phragmites australis* was introduced to the U. S. from the Old World. This new genotype, along with a continued increase in and variety of disturbances, may explain the heightened invasiveness of this species. Although invasive and natural communities of *Phragmites australis* are difficult to differentiate, this can be accomplished by considering the degree of disturbance at a site and observing a given stand over time to determine the degree of invasiveness. In invasive communities, associated species are highly variable, depending on the vegetation that has been invaded. Spreading in large colonies, *Phragmites* may eventually dominate disturbed areas at coverage up to 100%. More typically, though, scattered individuals of other species may occur, such as sparse *Morella cerifera (= Myrica cerifera)* shrubs, *Kosteletzkya virginica, Calystegia sepium, Boehmeria cylindrica, Typha angustifolia, Apocynum cannabinum, Rosa palustris, Polygonum* sp., and *Mikania scandens*. Vines of *Toxicodendron radicans* are also frequent, but typically occur at low cover. In areas where *Phragmites australis* is highly invasive, if *Phragmites australis* is a significant component of the vegetation but the vegetation retains sufficient species composition to retain its identity, the site is considered an unhealthy or degraded example of that vegetation type. In these same areas, if *Phragmites australis* cover is so high that native species have been excluded and the original community is no longer recognizable, then the occurrence falls within an invasive association within the *Phragmites australis* Tidal Herbaceous Alliance (A.1477).
Management Concerns: *Phragmites australis* dominated marshes are not target communities for freshwater marshes. Areas dominated by this species are often disturbed or native communities with similar tidal tolerances (at, or near, mean high tide). Once established *Phragmites* can be difficult to eradicate. As such, management of this species should focus primarily on preventing continued establishment, eliminating small colonies, and subsequently reducing large populations.

Typha (angustifolia, latifolia) - (Schoenoplectus spp.) Eastern Herbaceous Vegetation

Common Name: Eastern Cattail Marsh
Unique Identifier: CEGL006153
Classification Approach: International Vegetation Classification (IVC)
Range: These tall emergent marshes are common throughout the northeastern United States and adjacent Canadian provinces. They occur in New Jersey, Pennsylvania, and Delaware in the Delaware Estuary.
Environmental Description: This community occurs in permanently flooded basins, often as part of a larger wetland mosaic and associated with lakes, ponds, or slow-moving streams. The substrate is muck over mineral soil. Lacustrine cattail marshes typically have a muck-

bottom zone bordering the shoreline, where cattails are rooted in the bottom substrate, and a floating mat zone, where the roots grow suspended in a buoyant peaty mat. This association is often found in impounded waters.

Vegetation Description: Tall graminoids dominate the vegetation; scattered shrubs are often present (usually totaling less than 25% cover) and are frequently shorter than the graminoids. Trees are absent. Bryophyte cover varies and is rarely extensive; bryophytes are mostly confined to the hummocks. *Typha angustifolia* (narrowleaf cattail), *Typha latifolia* (broadleaf cattail), or their hybrid *Typha X glauca* (blue cattail) dominate, either alone or in combination with other tall emergent marsh species. Associated species vary widely; sedges, such as *Carex lurida* (sallow sedge), *Carex pellita* (woolly sedge), *Scirpus cyperinus* (woolgrass bulrush), and bulrushes, such as *Schoenoplectus americanus* (chairmaker's bulrush) and *Schoenoplectus acutus* (hardstem bulrush), occur along with patchy grasses, such as *Calamagrostis canadensis* (bluejoint). Broad-leaved herbs include *Thelypteris palustris* (eastern marsh fern), *Asclepias incarnata* (swamp milkweed), *Impatiens capensis* (orange jewelweed), *Sagittaria latifolia* (broadleaf arrowhead), *Scutellaria lateriflora* (blue skullcap), *Sparganium eurycarpum* (giant bur-reed), and *Verbena hastata* (swamp verbena). Floating aquatics such as *Lemna minor* (lesser duckweed) may be common in deeper zones. Shrub species vary across the geographic range of this type; in the northern part of its range, *Ilex verticillata* (common winterberry) and *Spiraea alba* (white meadowsweet) are common.

Characteristic Species: *Typha angustifolia* (narrowleaf cattail), *Typha latifolia* (broadleaf cattail)

Dynamics/Successional Trajectory: This association is often found in impounded waters and detention basins.

Reference Sites: Quakertown Swamp, State Game Lands 139, Bucks County, PA

Global and State Conservation Ranks and Reasons: G5 (1-Dec-1997). DE: SNR, NJ: S5, PA: SNR.

VegBank Link for Plot Data: http://vegbank.org/natureserve/element_global.2.685511

References: Breden 1989, Breden et al. 2001, CAP pers. comm. 1998, Clancy 1996, Cowardin et al. 1979, Eastern Ecology Working Group n.d., Edinger et al. 2002, Fike 1999, Gawler 2002, Grace and Wetzel 1981, Harrison 2004, Metzler and Barrett 2001, Northern Appalachian Ecology Working Group 2000, Rawinski 1984, Sperduto and Nichols 2004, Swain and Kearsley 2001, Thompson 1996, Thompson and Sorenson 2000

Management Concerns: *Typha* communities at the Refuge occur at, or near, mean high tide. As such, there is high potential for invasion by *Phragmites australis*. Management of *Typha* communities should consist primarily of invasion prevention.

Phragmites australis Dominated Marsh (see description under Freshwater Tidal Marsh)

Translated Name: Common Reed Tidal Herbaceous Alliance

Typha angustifolia - Hibiscus moscheutos Herbaceous Vegetation

Translated Name: Narrowleaf Cattail - Eastern Rosemallow Herbaceous Vegetation
Unique Identifier: CEGL004201
Classification Approach: International Vegetation Classification (IVC)
Range: This association occurs along the Atlantic coast from Maine to Virginia and possibly to South Carolina. It occurs in Delaware and New Jersey in the Delaware Estuary.
Environmental Description: This association occurs in oligohaline to mesohaline areas of tidal marshes (0.5-18 ppt). In estuarine systems, it can occur in the uppermost zone of brackish marshes where there is freshwater influence; it receives diurnal tidal flooding of brackish water. In salt marshes behind barrier beaches, it can occur in the upper reaches of larger tidal creeks within brackish areas and also at the upland border where there is significant freshwater input from the adjacent upland; here it receives irregular tidal flooding only during high spring tides. Substrate is muck or peat, and there is often an accumulation of *Typha* (cattail) litter.
Vegetation Description: The vegetation of this tall graminoid vegetation instead is a mixture of freshwater and saltmarsh species dominated by *Typha angustifolia* (narrowleaf cattail). *Phragmites australis* (common reed), *Typha latifolia* (broadleaf cattail), *Spartina cynosuroides* (giant cordgrass), or *Schoenoplectus pungens* (common threesquare) can codominate. The *Phragmites australis* (common reed) component is the native strain (Saltonstall 2002). Common associates include *Hibiscus moscheutos* (eastern rosemallow), *Schoenoplectus pungens* (common threesquare), *Impatiens capensis* (orange jewelweed), *Amaranthus cannabinus* (water-hemp), *Peltandra virginica* (green arrow-arum), and *Bidens* (beggarticks) spp., plus *Spartina cynosuroides* (giant cordgrass) in the south. Other infrequent associates include *Mikania scandens* (climbing hempvine), *Pluchea odorata* (sweetscent), *Polygonum punctatum* (dotted smartweed), *Eleocharis* (spikerush) spp., and *Schoenoplectus robustus* (alkali bulrush), plus *Schoenoplectus americanus* (chairmaker's bulrush) farther south. Species from adjacent high salt marsh may also be present.
Characteristic Species: *Hibiscus moscheutos* (eastern rosemallow), *Typha angustifolia* (narrowleaf cattail)
Dynamics/Successional Trajectory: Brackish marsh complexes commonly occur as mosaics of patches dominated by a single graminoid species. Patches dominated by *Typha angustifolia* (narrowleaf cattail) tend to occur where there is more freshwater influence near the upper reaches of estuaries or at the upland border of high salt marshes where there is freshwater input from the surrounding upland. As the marsh becomes more brackish, *Schoenoplectus pungens* (common threesquare) or *Spartina patens* (saltmeadow cordgrass) can become dominant. As the marsh becomes less brackish, *Peltandra virginica* (green arrow-arum), *Pontederia cordata* (pickerelweed), *Acorus calamus* (sweetflag), *Schoenoplectus tabernaemontani* (softstem bulrush), and *Zizania aquatica* (Indian wild rice) can become more prevalent. The pattern of alternating dominance between *Typha angustifolia* (narrowleaf

cattail) and *Phragmites australis* (common reed) that can occur in these environmental settings may reflect disturbance history of the site and of the surrounding watershed.
Reference Sites: widespread, DE; Hancock Bridge on Alloway Creek, Salem County, NJ; Supawna Meadows NWR (North bank of Mill Creek), NJ
Global and State Conservation Ranks and Reasons: G4G5 (19-Jan-2006). DE: S4, NJ: S4. This common small-patch community occurs in the estuarine areas of up to 13 northeastern states, several of which rank this vegetation as S4.
VegBank Link for Plot Data: http://vegbank.org/natureserve/element_global.2.683268
References: Bowman 2000, Breden 1989, Breden et al. 2001, Cahoon and Stevenson 1986, Coulling 2002, Dowhan and Rozsa 1989, Eastern Ecology Working Group n.d., Edinger et al. 2002, Ferren et al. 1981, Fleming 2001, Fleming and Moorhead 1998, Fleming et al. 2001, Gawler 2002, Good and Good 1975b, Harrison 2001, Harrison 2004, Hill 1986, Klotz 1986, MENHP 1991, McCormick and Ashbaugh 1972, Metzler and Barrett 1992, Metzler and Barrett 2001, Odum et al. 1984, Rawinski 1984, Reschke 1990, Saltonstall 2002, Schafale 2000, Schafale 2003b, Schafale and Weakley 1990, Shreve et al. 1910, Sperduto 1994, Sperduto 1997a, Sperduto 2000b, Steury 1999, Swain and Kearsley 2001
Management Concerns: This community is naturally associated with tidal hydrology. Current Impoundment management is preventing this community from its full potential. Restoration of tidal influence to the Impoundment (or portions of it) will allow restoration of this community. Currently, many portions of this community are invaded by *Lythrum salicaria* and/or *Phragmites australis*.

Unidentified Wetland Community

Unique Identifier: N/A
Classification Approach: N/A
Summary: This community consists of non-tidal, freshwater wetlands dominated by herbaceous vegetation that bear no resemblance to identified communities. Variation typically results from large scale invasion by exotic species, primarily *Lythrum salicaria*, *Phragmites australis*, and to a lesser extent *Polyganum perfoliatum*. Alternatively, these areas may include native species assemblages altered by hydrology or other management. Native species identified in these areas include *Carex spp*., *Ludwigia palustris*, *Pluchea odorata*, include *Polyganum cespitosum*
Management Concerns: The unidentified nature of this community makes it difficult to manage toward a target community. However, this community does contain the Pennsylvania state endangered plant species *Pluchea odorata*. As such, management should focus primarily on invasive species control. Monitoring of species populations and densities will aid in monitoring trends and changes in this community and identify key components.

Open Water

System Name: Northern Atlantic Coastal Plain Sub-tidal Aquatic Bed (CES203.521)

Isoetes riparia Tidal Herbaceous Vegetation

Common Name: Estuary Quillwort Tidal Flat

Unique Identifier: CEGL006352

Classification Approach: International Vegetation Classification (IVC)

Range: This community occurs in New Jersey and possibly Delaware in the Delaware Estuary.

Environmental Description: This association occurs on fresh tidal mud flats with soft to semi-soft substrates in shallow waters associated with embayments, occurring behind beaches and sand spits, as well as along margins of estuaries. These occur in quiet waters where fine sediments accumulate.

Vegetation Description: The vegetation is sparse but is characterized by *Isoetes riparia* (riverbank quillwort). Associated species include *Cyperus bipartitus* (shining flatsedge), *Elatine americana* (American waterwort), *Sagittaria graminea* (grassleaf arrowhead), *Sagittaria subulata* (awl-leaf arrowhead), *Sagittaria calycina* (hooded arrowhead), *Sagittaria montevidensis* (giant arrowhead), *Heteranthera reniformis* (kidneyleaf mud-plantain), *Crassula aquatica* (water pygmyweed), *Eriocaulon parkeri* (estuary pipewort), *Orontium aquaticum* (golden club), *Gratiola virginiana* (roundfruit hedge-hyssop), *Eleocharis obtusa* (blunt spikerush), and in more muddy areas, *Schoenoplectus smithii* (smith's clubrush). This may be the potential habitat of *Micranthemum micranthemoides* (Nuttall's mudflower). *Isoetes riparia* (riverbank quillwort) also occurs in non-tidal ponds in New Jersey.

Noteworthy Associated Plant and/or Animal Species: *Eriocaulon parkeri* (estuary pipewort)

Characteristic Species: *Isoetes riparia* (riverbank quillwort)

Dynamics/Successional Trajectory: The occurrence and extent of mud flats vary with coastline morphology and tidal amplitude. Mud flats are regularly flooded and exposed by diurnal tides (Whitlatch 1982).

Reference Sites: Rancocas Creek at Mill Creek (Willingboro Township) Park, Burlington County, NJ

Global and State Conservation Ranks and Reasons: GNR (1-Dec-1997). DE: SNR, NJ: S2S3.

VegBank Link for Plot Data: http://vegbank.org/natureserve/element_global.2.683281

References: Bartgis 1986, Bowman 2000, Breden 1989, Breden et al. 2001, Eastern Ecology Working Group n.d., Edinger et al. 2002, Harrison 2004, Rawinski 1984, Schafale 2000, Swain and Kearsley 2001, Whitlatch 1982

Management Concerns: Mudflats provide valuable foraging habitat for fish and shorebirds. Prohibiting armoring of streambanks and beds, channel dredging, excessive boat wake, or other activities that could potentially compromise natural morphology and stability should be the focus of mudflat management.

Acer negundo Forest

Common Name: Box-elder Floodplain Forest
Unique Identifier: CEGL005033
Classification Approach: International Vegetation Classification (IVC)
Description: This box-elder floodplain forest is found on floodplains in the southern, eastern, and midwestern United States. Locally, It occurs in the Piedmont region in Pennsylvania and in the Coastal Plain and Piedmont regions in New Jersey and Delaware. Stands occur on large rivers in the active floodplain and on sandbars, and may form farther from the riverfront following disturbance. They are typically temporarily flooded in the spring. These early successional forests are dominated by *Acer negundo*. Other characteristic species include *Platanus occidentalis, Celtis laevigata, Acer rubrum, Liquidambar styraciflua, Acer saccharinum, Ulmus alata, Ulmus rubra, Carpinus caroliniana, Morus rubra*, and *Populus deltoides*. The shrub and herb layers range from sparse to relatively lush, and the vine component often is heavy. The range, dynamics, and variability of this type is complicated by the 'weedy' nature of *Acer negundo*. For example, disturbed stands in the *Fraxinus pennsylvanica - Ulmus americana - Celtis (occidentalis, laevigata)* Temporarily Flooded Forest Alliance (A.286) often become dominated by *Acer negundo*.
Characteristic Species: *Acer negundo* (box-elder)
Dynamics/Successional Trajectory: This type is an early-successional community that arises from natural and cultural disturbances on floodplains. Stands also occur where occasional flash floods create extensive open alluvial deposits that may be colonized by this type.
Reference Sites: No reference sites were identified because this community type is not considered a desired community for restoration in the Delaware Estuary.
Global and State Conservation Ranks and Reasons: G4G5 (28-Mar-2003). DE: SNR, NJ: SNR, PA: SNR. As currently defined this is a broad-ranging community type. However, the range, dynamics, and variability of this type is complicated by the "weedy" nature of *Acer negundo*. More information may be needed to clarify the extent to which this type represents purely natural vegetation. Some stands may develop following disturbance of other natural bottomland communities.
VegBank Link for Plot Data: http://vegbank.org/natureserve/element_global.2.686021
References: Blair 1938, Campbell pers. comm., Fleming et al. 2001, Foti pers. comm., Harrison 2004, Hoagland 2000, INAI unpubl. data, Leahy pers. comm., Patterson and DeSelm 1989, Schotz pers. comm., Southeastern Ecology Working Group n.d., TDNH unpubl. data, Zollner pers. comm.
Management Concerns: This early successional community is not considered a desired target community for restoration in the Delaware Estuary. Some stands may develop following disturbance of other natural bottomland communities. As such, management should focus on invasive species control and promoting natural succession into some other community type.

Acer rubrum Forest

Common Name: Red Maple Forest
Unique Identifier: N/A
Classification Approach: N/A
Description: This red maple forest is found on several isolated portions of the Refuge. Acer rubrum dominates (> 90%) the canopy with an understory comprised of *Cornus amomum* and *Polyganum cespitosum*.
Management Concerns: This community is likely a degraded version of another identified community type and is not a desired target community for restoration. As such, management should focus on invasive species control and promoting natural succession into some other community type.

Acer – Elymus Forest (Acer saccharinum - Acer negundo/Ageratina altissima - Laportea canadensis - (Elymus virginicus) Forest)

Common Name: Piedmont/Central Appalachian Silver Maple Forest
Unique Identifier: CEGL006217
Classification Approach: International Vegetation Classification (IVC)
Summary: This is a forested community of large river floodplains in the Mid-Atlantic states of Maryland, Virginia, and West Virginia, possibly extending into Pennsylvania. These forests occupy banks and first bottoms of major rivers with nutrient-rich silt loams, sand loams, and sands that are temporarily inundated, annually or less often, in major flood events. Canopies are closed and dominated by *Acer saccharinum*, with *Acer negundo* dominating a subcanopy layer. Other minor overstory and understory associates include *Populus deltoides, Celtis occidentalis, Fraxinus pennsylvanica, Ulmus americana*, and *Juglans nigra*. Shrub layers range from sparse to dense but are usually dominated by *Lindera benzoin*. Herb layers are dominated by *Ageratina altissima, Laportea canadensis, Impatiens pallida, Viola sororia, Leersia virginica, Verbesina alternifolia, Urtica dioica ssp. dioica, Elymus virginicus, Elymus riparius, Geum canadense, Pilea pumila, Rudbeckia laciniata*, and *Cryptotaenia canadensis*. Vines of *Toxicodendron radicans* and *Parthenocissus quinquefolia* are common. Early-successional stands are usually strongly dominated by even-aged *Acer saccharinum*. This type was defined to cover *Acer saccharinum* forests of the Mid-Atlantic Piedmont and Central Appalachians. It was split off from the more broadly defined *Acer saccharinum - Ulmus americana - (Populus deltoides)* Forest (CEGL002586).
References: Eastern Ecology Working Group of NatureServe. No date., Fleming, G. P., and P. P. Coulling. 2001, Lea, C. 2000, Thomson, D., A. M. Gould, and M. A. Berdine. 1999, Virginia Division of Natural Heritage 2003, Vanderhorst, J. 2000b.
Management Concerns: These communities are being invaded by exotic species. *Allaria petiolata* is the most frequent and widespread species noted. Additional invasive species found within this community include *Ailanthus altissema, Cephalanthus orbiculatus, Humulus japonica, Lonicera japonica, Polyganum cuspidatum, Polyganum perfoliatum,* and *Rosa multiflora*. At the Refuge, this community differs from the more broadly defined *Acer saccharinum - Ulmus americana - (Populus deltoides)* Forest (CEGL002586) by its rare occurrences of *Ulmus* and *Populus* species and its significant presence of *Elymus* in the understory.

Acer - Fraxinus - Ulmus Forest (Acer (rubrum, saccharinum) - Fraxinus spp. - Ulmus americana Forest)

Common Name: Maple - Ash - Elm Swamp Forest

Unique Identifier: CEGL005038

Classification Approach: International Vegetation Classification (IVC)

Range: This association is found throughout the Midwestern United States and parts of the eastern United States, ranging from Pennsylvania west to Minnesota, and south to Arkansas. It also occurs in all three states of the Delaware Estuary.

Environmental Description: This community occurs on temporarily flooded soils along major rivers and smaller

perennial streams. Soils may be well-drained and sandy, more loamy on infrequently flooded bottomlands and levees, or deep silts on stabilized sites along larger rivers. The structure and composition of the type is influenced by the flooding regime. Floods leave river-deposited debris on the forest floor, ice scars on trees, and abandoned channels that retain water at or above the level of the main river channel.

Vegetation Description: Canopy cover is more-or-less closed and dominated by *Acer saccharinum* (silver maple). Codominants may include *Platanus occidentalis* (sycamore), *Acer negundo* (box-elder), and *Betula nigra* (river birch). Associated species may include *Ulmus americana* (American elm), *Ulmus rubra* (slippery elm), *Salix nigra* (black willow), *Celtis occidentalis* (common hackberry), and *Fraxinus pennsylvanica* (green ash). The shrub and sapling layer is often open (<25% cover). Species that may be present include *Sambucus canadensis* (American elder) or *Lindera benzoin* (northern spicebush). Woody and herbaceous vines can be prominent, including, among the woody vines, *Parthenocissus quinquefolia* (Virginia creeper) and *Vitis riparia* (riverbank grape). Herbaceous vines species include *Apios americana* (groundnut), *Amphicarpaea bracteata* (American hog-peanut), and *Echinocystis lobata* (wild cucumber). Herbaceous grasses, forbs, and ferns dominate the ground layer, including *Symphyotrichum lateriflorum* (calico aster), *Boehmeria cylindrica* (small-spike false nettle), *Elymus virginicus* (Virginia wild rye), *Impatiens pallida* (yellow jewelweed), *Laportea canadensis* (Canadian wood nettle), *Matteuccia struthiopteris* (ostrich fern), *Onoclea sensibilis* (sensitive fern), *Pilea pumila* (Canadian clearweed), *Urtica dioica* (stinging nettle), and others.

Characteristic Species: *Acer saccharinum* (silver maple)

Dynamics/Successional Trajectory: The structure and composition of the type is influenced by the flooding regime, which is typically an annual flooding of relatively brief duration (several weeks), but may be absent in dry years or extensive during flash-flood years. Floods leave river-deposited debris on the forest floor, ice scars on trees, and abandoned channels that retain water at or above the level of the main river channel.

Reference Sites: Christiana River, DE; White Clay Creek, DE; Delaware Water Gap, PA (outside estuary); Crosswicks

Creek at Provinceline Road, NJ; near Namanock Island in the Delaware Water Gap National Recreation Area, PA;

Shapnack Island in the Delaware Water Gap National Recreation Area, PA

Global and State Conservation Ranks and Reasons: G4? (3-Oct-1996). DE: SNR, NJ: SNR, PA: SNR. There has been significant conversion of stands to agriculture, hydrologic modifications due to river dams, etc., and siltation caused by modified flooding regimes.

VegBank Link for Plot Data: http://vegbank.org/natureserve/element_global.2.686814

References: Anderson 1996, CAP pers. comm. 1998, Eyre 1980, Fike 1999, INAI unpubl. data, MNNHP 1993, Midwestern Ecology Working Group n.d., TDNH unpubl. data, WINHIP unpubl. data, WPC and TNC 2002

Management Concerns: This community is found primarily along the southern edge of the Impoundment on the remnants of the Chester Short Line railway. While being relatively intact, this community is being invaded by exotic species. Vines, such as *Lonicera japonica* and *Polyganum perfoliatum* are the most frequent and widespread species noted. While the shrub layer is healthy, it has minor encroachment by *Ligustrum arvense* and *Rosa multiflora*. Additional invasive species found within this community include *Lythrum salicaria* and *Phragmites australis along the* Impoundment edges. Westervelt notes that Polyganum cuspidatum and Microstegium are also frequent invaders of this association.

Acer – Ulmus – Populus Forest Acer saccharinum - Ulmus americana - (Populus deltoides) Forest

Common Name: Silver Maple - Elm - (Cottonwood) Forest

Unique Identifier: CEGL002586

Classification Approach: International Vegetation Classification (IVC)

Summary: This silver maple - elm - cottonwood forest community is found throughout the midwestern United States and parts of the eastern United States. Stands occur on large, regularly flooded floodplains. Canopy cover is more-or-less closed and dominated by *Acer saccharinum*. Codominants may include *Populus deltoides, Platanus occidentalis, Ulmus americana, Ulmus rubra, Salix nigra, Acer negundo, Betula nigra, Celtis occidentalis*, and *Fraxinus pennsylvanica*. The shrub and sapling layer is often open (<25% cover). Species that may be present include *Sambucus canadensis* or *Lindera benzoin*. Woody and herbaceous vines can be prominent, including, among the woody vines, *Parthenocissus quinquefolia* and *Vitis riparia*. Herbaceous vines species include *Apios americana, Amphicarpaea bracteata*, and *Echinocystis lobata*. Herbaceous grasses, forbs, and ferns dominate the ground layer, including *Symphyotrichum lateriflorum (= Aster lateriflorus), Boehmeria cylindrica, Elymus virginicus, Impatiens pallida, Laportea canadensis, Matteuccia struthiopteris, Onoclea sensibilis, Pilea pumila, Urtica dioica*, and others.

Management Concerns: Some occurrences of this community exhibit some of the worst effects of overbrowsing by whitetail deer. In these areas, almost an entire lack of shrub species was recorded. In addition, many of the herbaceous species recorded are considered browse resilient, such as *Eupatorium rugosum*. *Allaria petiolata* dominates much of the groundlayer in some areas while vines such as *Humulus japonica* and *Lonicera japonica* are the also frequent. Additional invasive species found within this community include *Ailanthus altissema*, *Cephalanthus orbiculatus, Lythrum salicaria, Phragmites australis,* and *Polyganum cuspidatum*.

Prunus – Acer – Quercus Forest (Prunus serotina - Acer rubrum - Amelanchier canadensis - Quercus spp. Forest Alliance)

Translated Name: Black Cherry - Red Maple - Canada Serviceberry - Oak species Forest Alliance

Unique Identifier: A.237

Classification Approach: International Vegetation Classification (IVC)

Summary: This alliance includes temperate deciduous forests and scrub forests comprised of early-successional species. The canopy may contain *Prunus serotina var. serotina, Amelanchier canadensis, Acer rubrum, Liriodendron tulipifera, Fraxinus americana, Nyssa sylvatica, Photinia pyrifolia (= Aronia arbutifolia)*, and *Sassafras albidum* in varying proportions. *Pinus taeda, Diospyros virginiana*, and *Ilex opaca var. opaca* may occur locally on the Coastal Plain.

Some examples support vines in great abundance, such as *Smilax rotundifolia, Smilax glauca, Parthenocissus quinquefolia*, and *Toxicodendron radicans*. Herbs are of variable cover, depending on the degree of sunlight penetrating the canopy. Herbaceous composition is widely variable and may include both native and exotic species. The substrate varies from pure sand and loamy sands in coastal regions, or loam in the interior.

References: Bellis 1992, Boule 1979, Dunlop and Crow 1985, Eyre 1980, Higgins, E. A. T., R. D. Rappleye, and R. G. Brown. 1971, Hill, S. R. 1986, Martin, W. E. 1959b, Sneddon, L., M. Anderson, and K. Metzler. 1994, Stalter, R. 1979, Swain, P. C., and J. B. Kearsley. 2001.

Management Concerns: This community occurs in areas that were largely unvegetated in the 1968 plant survey. Intactness varies between occurrences, however most are impacted by excessive browse and invasive species colonization. *Allaria petiolata, Lonicera japonica,* and/or *Microstegium vinemium* dominate much of the groundlayer while vines such as *Cephalanthus orbiculatus* are also frequent. *Polyganum perfoliatum* is widespread in many canopy gaps and appears to be preventing canopy tree regeneration. Additional invasive species found within canopy include *Acer platanoides, Ailanthus altissema*.

Quercus - Liquidambar Forest (Quercus palustris - Quercus bicolor - (Liquidambar styraciflua) Mixed Hardwood Forest)

Common Name: Pin Oak Mixed Hardwood Forest

Unique Identifier: CEGL002432

Classification Approach: International Vegetation Classification (IVC)

Summary: This pin oak - swamp white oak forest community type is found in the central United States. Stands occur on wet, poorly drained depressions and contain a closed to partially open canopy dominated by *Quercus palustris* and *Acer rubrum*. Oaks should comprise at least 25% of the dominance in a stand. Other typical canopy associates may dominate, including *Liquidambar styraciflua, Nyssa sylvatica*, and *Quercus bicolor*. Other wetland hardwood species can occur, including *Acer saccharinum, Betula nigra, Quercus macrocarpa*, and *Quercus rubra*. Shrub and vine species are variable and may include *Cornus* spp., *Lindera benzoin, Parthenocissus quinquefolia*, and *Sambucus canadensis*. Herbaceous species also vary widely. Herbaceous species noted from a site in the Western Allegheny Plateau include *Cinna arundinacea* (dominant), with other associates including *Carex blanda, Carex laxiculmis, Carex rosea, Elymus riparius, Elymus virginicus, Cardamine bulbosa, Cardamine pensylvanica, Claytonia virginica, Oxalis violacea*, and *Podophyllum peltatum*.

References: Anderson, D. M. 1982, Anderson, D. M. 1996, Braun, E. L. 1936, Bryant, W. S. 1978, Evans, M. 1991, Fike, J. 1999, Iowa Natural Natural Areas Inventory. No date, Leahy, Mike. pers. comm., Meijer, W., J. J. N. Campbell, H. Setser, and L. E. Meade. 1981, Midwestern Ecology Working Group of NatureServe. No date, Tennessee Division of Natural Heritage Unpublished data.

Management Concerns: This community is the only forest community at the Refuge identified as globally rare (G3) and state imperiled (S2). Intactness varies between occurrences, however most are impacted by excessive browse and invasive species colonization. *Allaria petiolata, Lonicera japonica,* and/or *Microstegium vinemium* dominate much of the groundlayer while vines such as *Cephalanthus orbiculatus* are also frequent. *Polyganum perfoliatum* is widespread in many canopy gaps and appears to be preventing canopy tree regeneration. Additional invasive species found within canopy include *Acer platanoides* and *Ailanthus altissema*. Gray poplar (*Populus x canescans*) is found as primary regeneration in a few occurrences and should be prevented from establishing.

Salix nigra Temporarily Flooded Shrubland

Common Name: Willow River-Bar Shrubland
Unique Identifier: CEGL006065
Classification Approach: International Vegetation Classification (IVC)
Range: This shrubland occurs in the eastern United States from New Hampshire and Vermont south to Pennsylvania. It occurs in Pennsylvania in the Delaware Estuary.
Environmental Description: It occurs on cobble substrates with sand and gravel in areas that are flooded only during high-water events but receive winter ice-scour. It occupies an intermediate position along disturbance gradient between open, herbaceous cobble shores and higher floodplain forests.
Vegetation Description: This is a willow shrubland of low riverbanks along moderate- to high-energy rivers in the Northeast and High Allegheny Plateau. *Salix nigra* (black willow) is often dominant or codominant with other willows or dogwoods. Less frequent shrubs and tree saplings include *Platanus occidentalis* (sycamore), *Salix eriocephala* (Missouri willow), *Salix sericea* (silky willow), *Alnus incana* (speckled alder), *Alnus serrulata* (smooth alder), *Alnus viridis* (green alder) (infrequent), *Cornus amomum* (silky dogwood), *Cornus sericea* (red-osier dogwood), *Spiraea alba var. latifolia* (broadleaf meadowsweet), *Platanus occidentalis* (sycamore), and *Populus deltoides* (eastern cotto nwood). The herbaceous layer is typically sparse with variable composition, including *Carex torta* (twisted sedge), *Carex trichocarpa* (hairy-fruit sedge), *Panicum dichotomiflorum* (fall panicgrass), *Dichanthelium clandestinum* (deer-tongue witchgrass), *Echinochloa crus-galli* (large barnyard grass), *Phalaris arundinacea* (reed canarygrass), *Calamagrostis canadensis* (bluejoint), *Apocynum cannabinum* (Indian-hemp), *Agrostis* (bentgrass) spp., *Solidago gigantea* (giant goldenrod), *Solidago rugosa* (wrinkleleaf goldenrod), *Eupatorium maculatum* (spotted joe-pyeweed), *Lysimachia terrestris* (swamp-candles), *Polygonum* (smartweed, knotweed) spp., and *Bidens* (beggarticks) spp. Invasive, exotic species can be problematic in this community, including *Polygonum cuspidatum* (Japanese knotweed), *Tussilago farfara* (colt's-foot), and *Cynanchum louiseae* (black swallow-wort).
Characteristic Species: *Carex torta* (twisted sedge), *Salix nigra* (black willow)
Dynamics/Successional Trajectory: This community is subject to extreme ice-scour events as well as erosion and deposition during floods. The clonal nature of most of the woody species in this community serves to stabilize the substrate and allows rapid regeneration of above-ground biomass following damage and removal caused by flooding/scour events. Unless flow regime is altered (i.e., flow manipulation from dams), this type is relatively persistent, with minor spatial shifts due to erosion and sedimentation during flood events. Flow regulation may cause a shift to more mature vegetation by reducing flood severity and duration.
Reference Sites: Shapnack Island, Delaware Water Gap National Recreation Area, PA
Global and State Conservation Ranks and Reasons: GNR (25-Mar-2003). PA: SNR.
VegBank Link for Plot Data: http://vegbank.org/natureserve/element_global.2.689581
References: Eastern Ecology Working Group n.d., Fike 1999, Gawler 2002, Metzler and Barrett 2001, Nichols et al. 2001, TNC and WPC 2004
Management Concerns: This community is primarily a wetland forest community found in various locations along Darby Creek. Most are impacted by invasive species colonization. Wetland invaders such as *Lythrum salicaria* and *Phragmites australis* are commonly found. *Allaria petiolata, Cephalanthus orbiculatus, Lonicera japonica, Polyganum cuspidatum,* and *Rosa multiflora* are common in drier areas.

Unidentified Forest Community

Unique Identifier: N/A

Classification Approach: N/A

Summary: This community consists of forests dominated by exotic tree species that bear no resemblance to identified communities. Found primarily in the East Impoundment Forest management unit, this forest is dominated by gray poplar (*Populus x canescans*), a genetic hybrid between the native big-tooth aspen (*Populus grandidentata*) and the Eurasian white poplar (*Populus alba*). This hybridized species dominates the existing canopy and subsequent regeneration.

Management Concerns: The unidentified nature of this community makes it difficult to manage toward a target community. However, given its surroundings and species present, it is likely that this community target is likely a *Quercus – Liquidambar* Forest (CEGL002432). As such, management should focus primarily on removal of the regenerating layers of gray poplar and invasive species control. Removal of some canopy gray poplars may be required to establish *Quercus palustris*. Monitoring of species populations and densities will aid in monitoring trends and changes in this community as a result of management. Other exotic, invasive species found in this community include *Ailanthus altissema, Allaria petiolata, Artemesia vulgaris, Celastrus orbiculatus, Humulus japonica, Lonicera japonica, Lonicera maackii, Microstegium vimeneum, Polyganum perfoliatum,* and *Rosa multiflora*.

Schizachyrium scoparium - Sorghastrum nutans Herbaceous Alliance

Translated Name: Little Bluestem - Yellow Indiangrass Herbaceous Alliance
Unique Identifier: A.1198
Classification Approach: International Vegetation Classification (IVC)
Summary: This alliance, comprising dry-mesic tallgrass vegetation and blackland prairies, is found primarily in the central United States and southern Canada. The vegetation of stands of this alliance is characterized by moderate to dense cover of medium and tall grasses and a diverse mixture of forbs. Woody species are absent to rare but can be uncommon in some communities. The most abundant species across the range of this alliance are *Bouteloua curtipendula, Schizachyrium scoparium*, and *Sorghastrum nutans*. Other graminoids species common in parts of this alliance are *Andropogon gerardii, Bouteloua hirsuta, Carex* spp., *Danthonia spicata, Hesperostipa spartea (= Stipa spartea)*, and *Sporobolus heterolepis*. In the far southern part of the alliance's range, associations can contain *Andropogon glomeratus, Panicum virgatum*, and *Sporobolus clandestinus*. Some of the many forbs which can be found in this alliance include *Symphyotrichum ericoides (= Aster ericoides), Echinacea pallida, Helianthus* spp., *Hedyotis nigricans var. nigricans* (in Illinois and Missouri), *Lespedeza capitata* (especially on sand), *Lithospermum canescens, Clinopodium arkansanum (= Calamintha arkansana)* (in Illinois), and *Solidago nemoralis*. In the Southeast, *Ratibida pinnata* or *Baptisia australis var. minor* may be found, as well as a variety of forbs with Coastal Plain affinities. Woody species that are found in stands of this alliance are those that can adapt to the dry to dry-mesic conditions, such as *Acer rubrum* and *Juniperus virginiana*. This alliance includes remnant prairie-like vegetation occupying small areas (<1 acre) of mafic substrates in the Southern Blue Ridge plateau underlain by magnesium-rich bedrock; this vegetation is disjunct from the principal distribution of this alliance. Fire presumably played an important ecological role in maintaining natural stands of this vegetation in the pre-settlement landscape.
Management Concerns: This community occurs in locations where previous grassland restoration has focused on establishment of primarily warm-season grasses. No invasive species were present in these areas during field surveys. However, these communities are susceptible to invasion by species already present at the Refuge: *Acer platanoides, Ailanthus altissema, Artemesia vulgaris, Lonicera japonica, Lonicera maackii, Polyganum cuspidatum, Polyganum perfoliatum,* and *Rosa multiflora*. Grassland communities under natural circumstances rely on fire to remove shrubs and establish seeds. While fire is the preferred method for maintaining grasslands, mowing is acceptable as a secondary measure.

Unidentified Meadow Community

Unique Identifier: N/A
Classification Approach: N/A
Summary: This community consists of grasslands dominated by native and/or exotic cool-season herbaceous species that bear no resemblance to identified communities. Found primarily in areas where right of way or other management prevents successional growth, repeated mowing has led to dominance of cool season grasses such as *Dactylis glomerata, Digitaria sanguinalis, Setaria spp.* and other mowing-tolerant vegetation such as *Apocynum*

cannabinum, Carex. spp., Conyza canadensis, Erigeron spp., Lamium amplexicaule, Solidago spp., Sonchus oleraceus, and *Vicia spp*.

Management Concerns: The unidentified nature of this community makes it difficult to manage toward a target community. As such, management should focus primarily on restoring these areas to native species assemblages and invasive species control. Exotic, invasive species found in this community include *Humulus japonica, Lythrum salicaria, Phragmites australis, Polyganum perfoliatum,* and *Rosa multiflora*.

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APPENDIX C

INVASIVE SPECIES IDENTIFICATION AND CONTROL METHODS RESOURCES

The Nature Conservancy, Global Invasive Species Initiative
http://tncweeds.ucdavis.edu/esadocs.html
An excellent website featuring the Weed Control Methods Handbook, printable documents on invasive species, photos, and papers on the latest control methods for particular species.

Plant Conservation Alliance, Alien Plant Working Group
http://www.nps.gov/plants/alien/
Weeds Gone Wild: Alien Plant Invaders of Natural Areas is a web-based project that provides information for the general public, land managers, researchers, and others on the threat and impacts of exotic, invasive plants.

U.S. Department of Agriculture, National Invasive Species Information Center
http://www.invasivespecies.gov/
Current issues and updates on plant, insect, and other biological invasive species.

U.S. Department of Interior, The Aquatic Nuisance Species Task Force
http://anstaskforce.gov/
An intergovernmental taskforce dedicated to preventing and controlling aquatic nuisance species.

The Invasive Species Specialist Group, Global Invasive Species Database
http://www.issg.org/database/welcome/
Includes information on ecology and control information on invasive species from around the world.

Virginia Department of Conservation and Recreation/Virginia Native Plant Society Cooperative Project, Invasive Plant Species of Virginia
http://www.dcr.state.va.us/dnh/invproj
Thirty printable fact sheets on invasive plants including a downloadable management document. Originally developed the state of Virginia, many species and control methods noted are applicable in other states.

United States Department of Agriculture, Forest Service Pest Alert
http://www.na.fs.fed.us/pubs/palerts.shtm
Comprehensive description and mapping of existing and emerging plant pests for states in the Northeast.

Animal and Plant Health Inspection Services (APHIS)
http://www.aphis.usda.gov/
National information on pests, information on pest detection and management. Includes links to information on invasive species, pest management, and emerging pests.

APPENDIX D

FISH SPECIES AND UTILIZATION: LOWER DARBY CREEK AND SURROUNDING HABITATS

Species		Habitat Use			
Scientific Name	Common Name	Spawning Area	Nursery Grounds	Shelter	Adult Forage
Freshwater Species					
Catostomus commersoni	White sucker	♦	♦		♦
Cyprinus carpio	Common carp	♦	♦		♦
Etheostoma olmstedi	Tessellated darter	♦	♦	♦	♦
Gambusia holbrooki	Eastern mosquitofish	♦	♦	♦	♦
Hybognathus regius	Eastern silvery minnow	♦	♦	♦	♦
Lepomis cyanellus	Green sunfish	♦	♦		♦
Lepomis gibbosus	Pumpkinseed	♦	♦		♦
Lepomis macrochirus	Bluegill	♦	♦		♦
Micropterus salmoides	Largemouth bass	♦	♦		♦
Notemigonus crysoleucas	Golden shiner	♦	♦	♦	♦
Notropis hudsonius	Spottail shiner	♦	♦	♦	♦
Poxomis nigromaculatus	Black crappie	♦	♦		♦
Umbra pygmaea	Eastern mudminnow	♦	♦	♦	♦
Estuarine-Marine Species					
Brevoortia tyrannus	Atlantic menhaden				♦
Fundulus diaphanus	Banded killifish	♦	♦	♦	♦
Fundulus heteroclitus	Mummichog	♦	♦	♦	♦
Leiostomus xanthurus	Spot	♦	♦		♦
Menedia beryllina	Inland silversides	♦	♦	♦	♦
Micropogonias undulatus	Atlantic croaker	♦	♦		
Trinectes maculatus	Hogchocker		♦	♦	♦
Anadramous Species					
Alosa pseudoherangus	Alewife	♦	♦	♦	
Alosa aestivalis	Blueback herring	♦	♦	♦	
Dorosoma cepedianum	Gizzard shad	♦	♦		♦
Morone saxatilis	Striped bass		♦		♦
Morone americana	White perch	♦	♦		♦
Catadromous Species					
Anguilla rostrata	American eel		♦	♦	♦

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APPENDIX E

REGIONAL COORDINATION AND COMMUNITY INVOLVEMENT

<table>
<tr><td>Volunteer Organizations</td><td colspan="2">The Friends of the Heinz Refuge is a 501(c)(3), non-profit cooperating association founded in 1997 to assist the United States Fish & Wildlife Service in carrying out its educational, interpretive, and public use missions. The Friends group is experienced and capable of expanding it's role into restoration and related educational programs. The Friends group can contribute significantly in the following areas:
Continue to assist USFWS staff with volunteer program development, public use, wildlife monitoring, restoration management evaluation, and securing funding through grants.
Acquire expertise in identification of invasive and native species and assisting with monitoring and control efforts.
Provide training and supervision of volunteer groups and surrounding landowners to manage invasive species and plant appropriate native species.
Assist with installation and maintenance of deer fencing, signage, nesting boxes, trails, and trail-side facilities.
Assist with fund raising events and development of eco-tourism at the Refuge.
Attend municipal and regional meetings such as the Darby Creek Valley Association, Tinicum-Fort Mifflin Trail, Fairmont Park Commission, Airport Expansion, and others to report on potential opportunities or concerns involving the Refuge and Darby Creek.</td></tr>
<tr><td colspan="2">Short Term Actions
Receive training from USFWS staff on invasive plant identification and control methods.
Organize and hold a Spring invasive plant and native plant workshop for landowners in the surrounding communities.
Continue to assist the USFWS in monitoring wildlife populations utilizing the Refuge.
Assist in creating partnerships with adjoining municipalities and landowners to control invasives in edge areas and right-of-ways adjoining the marsh.
Install and maintain deer fencing exclosures.
Develop, install, and maintain trail signage at plant communities or areas of interest.
Develop handbook for invasive plant identification and control that can be provided for volunteer training.
Identify garden clubs or other group(s) that will be willing to adopt the grounds of the Cusano Center and management units to provide maintenance and improvements.</td><td>Long Term Actions
Continue to assist the USFWS in carrying out its educational, interpretive, and public use missions.
Supervise volunteers eliminating vines in canopy trees, invasive shrubs, followed by easy to recognize invasives such as purple loosestrife, garlic mustard, and phragmites.
Focus volunteer recruitment on groups that can provide repeated assistance for selected management areas or specific tasks so that training time can be minimized.
Ongoing planting to reach diversity, structure, or function targets.
Acquire funding for a full time volunteer coordinator responsible for scheduling volunteers, attracting volunteer groups, and coordinating events.
Assist with eco-tours and install water trail directional signage and interpretive signage at plant communities or areas of interest.</td></tr>
</table>

<table>
<tr><td>Local Educational Institutions</td><td colspan="2">Elementary Schools
Delaware County Technical High School, 610-583-7620
Delaware County Middle School, 610-521-6870)
Delcroft (FT enrollment: 540), 610-522-4360
Norwood School (FT enrollment: 660), 610-237-6425
Leedom Elementary (; FT enrollment: 321), 610-534-1900
Tinicum Township (FT enrollment: 400), 610-847-5131
Other Educational Facilities
Cobbs Creek Environmental Education Center (CCEEC). Partner with education center to promote resources protection and sustainable land use practices. (215-685-1900)</td></tr>
<tr><td colspan="2">Short Term Actions
Compile a list of contacts and complimentary educational programs at nearby elementary and secondary schools. Annually update the list and mail materials explaining educational opportunities for teachers and students.
Seek private grants to subsidize transportation costs for school programs.
Continue current educational programs for students and expand offerings for teachers as needed to state educational standards in Pennsylvania and New Jersey.
Many schools now promote community service. Students can assist with invasive plant management of easily recognizable plants such as garlic mustard.</td><td>Long Term Actions
Develop additional self-guided educational tours and brochures for the students and the general public.
The tidal marsh is best experienced on the water. Consider developing facilities to bring larger groups of students into the tidal marsh via boat.
CCEEC in cooperation with Lincoln University and the University of the Sciences currently offers an advanced environmental science course high school juniors and seniors. The Refuge should consider partnering with CCEEC in this program to train potential future interns and to conduct short-term research studies.</td></tr>
</table>

Academic Institutions	The following colleges and universities have sponsored and participated in scientific studies that add to the body of knowledge about the Refuge. The work of teachers, students, and interns has contributed greatly to the understanding of the marsh and the surrounding ecosystems. Future research projects at the Refuge can compliment restoration by coordinating research with evaluation data needs, standardizing data collection methods, and providing quality assurance and control. • Widener University-Main Campus (About 7 Miles; Chester, Pa; Full-Time Enrollment: 3,646) • Delaware County Community College (About 9 Miles; Media, Pa; Ft Enrollment: 5,248) • University Of Pennsylvania (About 9 Miles; Philadelphia, Pa; Ft Enrollment: 19,324) • Drexel University (About 9 Miles; Philadelphia, Pa; Ft Enrollment: 10,823) • Saint Josephs University (About 9 Miles; Philadelphia, Pa; Ft Enrollment: 5,115) • Art Institute Of Philadelphia (About 10 Miles; Philadelphia, Pa; Ft Enrollment: 2,138) • MCP Hahnemann University (About 11 Miles; Philadelphia, Pa; Ft Enrollment: 2,198)

Short Term Actions

- Despite incredible gains in the scientific understanding of tidal, wetland, and forest ecosystems, these systems are extremely complex. Management of these systems must be prepared for non-linear, chaotic , and unpredicted responses to environmental change. The Refuge provides a convenient and invaluable field laboratory for the continued study of ecological processes and an unrivaled opportunity to train future ecologists and decision makers to manage wilderness in an urban setting.
- The restoration of filled areas with organic soils and areas with potentially contaminated soils require further evaluation to determine limiting factors. Factors that would interfere with recovery or restoration of these areas may include invasive seed banks, soil chemistry, nutrient cycling, hydrology, or other physical conditions.
- Additional inventories of flora and fauna are needed to identify potential rare and endangered species present.
- The Refuge being located within a major metropolitan area; adjacent to an international airport and interstate transportation corridor create obstacles for the successful movement, reproduction, and rearing of wildlife. Further study is needed on noise levels, migration hazards, and on other potential impact on wildlife related to the regional transportation network and urban landscape.

Long Term Actions

- Global sea level rise has been approximately six inches in the past century. Sea levels in the Delaware Estuary have risen roughly twice that amount. The Intergovernmental Panel on Climate Change (IPCC) predicts a global sea level rise of up to three feet in the twenty-first century, however prediction models vary and local predictions are not possible at this time. Further study is needed on Lower Darby Creek's capacity to adapt to these changes, the sea level fluctuations, tidal conditions, plant community zonation, distributory channels in the wetlands, stream flow into the Refuge, sediment transport, and marsh accretion rates.
- Adaptive management strategies proposed by this plan require well-planned baseline studies and monitoring to determine if measurable objectives are met and if restoration projects are on the right trajectory. The performance standards recommended in this plan and prior monitoring efforts should guide the scope and quality of research studies.
- Continue to pursue funding to support educational programs. Develop a strategy to extend the duration of educational programs and expand field school opportunities at the Refuge. Explore the potential market for a field school similar to the Humboldt Field Research Institute and similar programs.

<table>
<tr><td>Regional Organizations</td><td colspan="2">The following regional organizations share many of the same goals as the Refuge and coordination with these organizations will help address regional issues affecting the Refuge including water quality, stormwater, invasive plants, and watershed restoration. Some of the regional planning groups, potential partnerships, and mutual support include:
Darby Creek Valley Association (DCVA)
Philadelphia Water Dept. Education and Outreach
Delaware County Planning Commission
Delaware River Basin Commission (DRBC)
Regional conservation organizations</td></tr>
<tr><td colspan="2">Short Term Actions
Continue participation in Cobbs Creek Bikeway to determine the best bike path alignments and bike path design to and through the Refuge.
Support the DCVA’s mission to improve water quality, restore, and enhance lands within the Darby Creek watershed.
Support the Philadelphia Water Department’s comprehensive watershed management program that identifies and addresses water pollution sources and manages stormwater</td><td>Long Term Actions
Improve and continue contacts with regional conservation organizations ranging from the Wyncote Audubon Chapter to the Ducks Unlimited. For example, the Pennsylvania Chapter of Ducks Unlimited has over 14,000 members.
Support the estuary programs that identify and addresses water pollution sources and manage stormwater</td></tr>
</table>

Municipalities	The municipalities encompassing the Refuge have a significant role in promoting best land management practices, addressing stormwater concerns, regulating bordering land uses, policing, and supporting protection and restoration. The adjoining municipalities and contact information are listed below. This list does not include all of the municipalities in the Darby Creek watershed (which also contribute the overall health of the ecosystems and water quality of Darby Creek). • City of Philadelphia, 215-685-2697, 9 (Rec. District) also contact Transportation, Engineering and Planning • Darby Township, 610-586-1514 • Borough of Folcroft, 610-522-1305 • Borough of Norwood, 610-586-5800 • Borough of Prospect Park, 610-532-1007 • Ridley Township, 610-534-4800 • Tinicum Township, 610-521-3530

Short Term Actions

- Coordinate invasive control / IPM with appropriate municipal departments:
  - Tinicum: Contact Station at Route 420 and other open spaces
  - Prospect Park: Marina & Swim Club, Morton Homestead, and open spaces.
  - Ridley: Leedom Estates Park and others
  - Folcroft: Memorial and Montgomery
  - Norwood: Winona Park and others
  - Philadelphia: Elmwood Park & Cobbs Creek Park, Gbotti Recreation Center and Eastwick Regional Park, and other open space.
- Meet with other municipalities to discuss stormwater and flooding issues and identify concerns and potential solutions.
  - Tinicum Township flooding issues and possible tidal connection with Long Hook Creek.
  - Darby Creek watershed urban stormwater management practices.
  - Discuss reconnection of Bow Creek and Darby Creek with the City of Philadelphia.

Long Term Actions

- Work with USFWS staff to evaluate the need for motorized boating regulations to reduce water pollution, prevent erosion, or degradation of mudflats.
- Support USFWS in developing and implementing a regional deer population management program
- Support (either technically or financially) stream and riparian restoration and water quality improvements upstream of the Refuge within the Darby Creek watershed and tributaries.
- Preserve natural channels and mudflats by prohibiting installation of additional piers, docks, and bank armoring on Refuge lands.
- Continue relationship with surrounding municipalities and coordinate annually with police departments to evaluate enforcement needs.
- Coordinate restoration of tributaries including Hermesprota Creek, Muckinipattis Creek, and other tributaries to the Refuge.
- Promote volunteerism, events, and encourage residents to use best management practices through municipal newsletters or other publications.

<table>
<tr><td>Industrial and Commercial Land Owners</td><td colspan="2">Industrial and commercial landowners within the Darby Creek share the responsibility to minimize impacts to the Refuge and prevent potential impacts. Coordination with these landowners and operators will help address point and non-point source issues along with emergency coordination affecting the water and environmental quality in the Refuge. Private-public partnerships are a priority with the following organizations and landowners.
Sunoco, Inc. and Sun Pipeline Company
Philadelphia International Airport
In addition to these facilities, the Darby Creek Conservation Plan (Figure II-8 and Table II-13) identified 13 facilities within the Darby Creek Watershed listed on EPA's Toxic Release Inventory (TRI) that manufacture, process, or otherwise use toxic chemicals. Updates to this list can be identified using the inventory website: www.epa.gov/enviro/html/tris/tris_query.html</td></tr>
<tr><td colspan="2">Short Term Actions
Identify a list of major industrial and commercial and land uses that threaten water quality in Darby Creek and it's tributaries. Update the list based on information from local emergency services and the EPA TRI.
Continue involvement in remediation of properties which are sources of contamination to the lower Darby Creek including
Folcroft Landfill and Annex
Former Delaware County Incinerator
Former Delaware County Sewage Treatment Plant
Sun Oil-Darby Creek Tank Farm
Industrial Drive properties
Clearview Landfill
Austin Avenue Radiation Site</td><td>Long Term Actions
Involve adjacent property owners (pipeline, airport, PENNDOT) that are not currently managing invasive plants
Develop IPM Program for these areas
Participate/coordinate Spill Prevention, Control, and Countermeasure Plans or other environmental emergency action plans as related to protection of open water and tidal wetlands on Refuge lands.
Support (either technically or financially) stream and riparian restoration and water quality improvements upstream of the refuge.
Coordinate deer management with large commercial and industrial landowners near the Refuge.</td></tr>
</table>

Source: Delaware Riverkeeper Network, 2006.

APPENDIX F

DELAWARE RIVERKEEPER® NETWORK
Ecological Community Assessment Form

**Adapted from the National Vegetation Classification System Field Data Assessment Sheets*

Site Location and ID: _____

Observer: _____

Date: _____

Environmental Conditions and Setting: (soil type/conditions, hydrologic conditions, surrounding land use, etc.)

_____

_____

Vegetation Structure: (closed canopy forest, open meadow, meadow with occasional shrubs, etc.)

_____

_____

Vegetation Layer	Height	% Cover	Characteristic/Dominant Species*
Canopy Trees			
Shrubs			
Herbaceous			
Vines			
Moss/Lichen			

Ecological Influences: (land use history, known/existing disturbance, type/extent of invasive species*, animal use, environmental conditions, etc.)

_____

_____

_____

_____

_____

*Note extent of native/invasive species by estimated percent cover (if possible, map extent of populations):

>75%	= Dominant
75-50%	= Abundant
50-25%	= Frequent
25-5%	= Occassional
<5%	= Rare